N 72-29862

SPACE STATION DATA FLOW
Summary Technical Report

IBM No. 72W-00213

Huntsville

IBM

SPACE STATION DATA FLOW
Summary Technical Report

IBM No. 72W-00213

June 19, 1972

Prepared for the
Marshall Space Flight Center
National Aeronautics and Space Administration

Contract No NAS8-26798

Approved

C D Jackson, Study Manager

IBM Federal Systems Division, Electronics Systems Center/Huntsville, Alabama

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (cont)

LIST OF ILLUSTRATIONS (cont)

LIST OF ILLUSTRATIONS (cont)

LIST OF TABLES

INTRODUCTION AND SUMMARY 1

1 1 INTRODUCTION

This final report presents the results of the Space Station Data Flow Study performed for Marshall Space Flight Center (MSFC) by IBM The report is structured in a series of sections corresponding to the several tasks described in the study flow plan, providing an orderly arrangement of results as they were achieved during the program Extensive detail data whose presence would impede the flow of the report have been avoided when the data was available in other publications A Data Flow Plan, or Implementation Plan is included as the last section of the report.

1.1.1 OBJECTIVES

The goal of the study was to define a low cost interactive data dissemination system for Space Station experiment data, including

- facilities requirements and locations
- personnel requirements and locations
- phasing requirements and
- implementation cost

1 1.2 SCOPE

Data flow in this study was considered from Source to User The Source is the instrument or sensor, and the User is defined as the person or organization interested in receiving information from the data

This dictates consideration of Space Station on-board systems and techniques, transmission orbit to ground, data collection, processing and archiving, and dissemination to users on a world-wide basis Source of data was primarily from orbiting experiments in the Space Station, free-flying or in Sortie Mission However, consideration was also given to data from ground experiment testing as well as ground truth and, in the case of Earth Observations, underflight data gathered via aircraft

1.1.3 STUDY GUIDELINES

Basic guidelines were established at the beginning of the study, then were maintained and refined through a close working relationship between cognizant NASA and IBM study team members

1.1.3.1 Data Inputs

Earliest guidelines in the study formed the starting point for analysis to determine the data inputs to the ground data handling system These consisted of the following

- Reference Earth Orbital Research and Applications Investigations (Blue Book) January 1971 – experiment definition
- Experiments Requirements Summary – Martin Marietta (Green Book) April 1971 – experiment data rates

- Crew Operations – Modular Space Station – McDonnell Douglas June 1971 – detailed experiment scheduling

- Case 534G – McDonnell Douglas – baseline experiment schedule, covering 40 quarters of Space Station operations

1.1.3.2 Communications

A Tracking and Data Relay Satellite System was assumed to be in operation during the Space Station period This was specified for planning purposes in "Characteristics of Future Ground Network and Synchronous Satellite Communications System for Support of NASA Earth Orbital Missions "

1.1.3.3 Cost

Two basic cost guidelines were used throughout the study

- Minimize early expenditures

- Low total cost

1 1.3.4 Approach

Three guidelines controlling the development of the approach to data management in this study were maintained as basic throughout the study

- NASA will perform a minimum of data processing as a service This implies that highly specialized and detailed processing will be done by the user but permits that processing common to many users to be done by NASA in order to minimize overall national cost

- Use existing and planned archiving facilities Minimize the amount of archiving that must be done by NASA

- Use existing NASA facilities This guideline assumes that the experiment program handled by the proposed system is virtually the total NASA earth orbital experiment program in the 1980's This is easily appreciated when it is considered that the system is expected to handle data from Space Station, Sortie Missions and Free Flyers

(Note Although the experiment package defined by case 534G and used as a main theme in this study is, indeed, a Space Station program, it was not overlooked, that a similar experiment program could be carried out on a less integrated basis than in a Space Station For example, in order to take advantage of differing orbits, a series of sortie missions, free flyers, and perhaps manned satellites could conduct the same series of experiments called for in Case 534G The data load should remain the same on the ground, which is of prime importance in the study But there would be added complexities in communications to ground, mission management and likely in experiment interaction

1.1.4 ASSUMPTIONS

Certain assumptions that were key to the study emerged as corollaries of the guidelines above

- 30 day shuttle resupply cycle – for crew exchange, replenishment of consumables, experiment program modifications, and return of data and specimens
- 4 day shuttle visit during which no experiments are run and no data is generated

1.2 APPROACH

The study consisted of ten technical tasks arranged in four phases, as shown in Figure 1 2-1

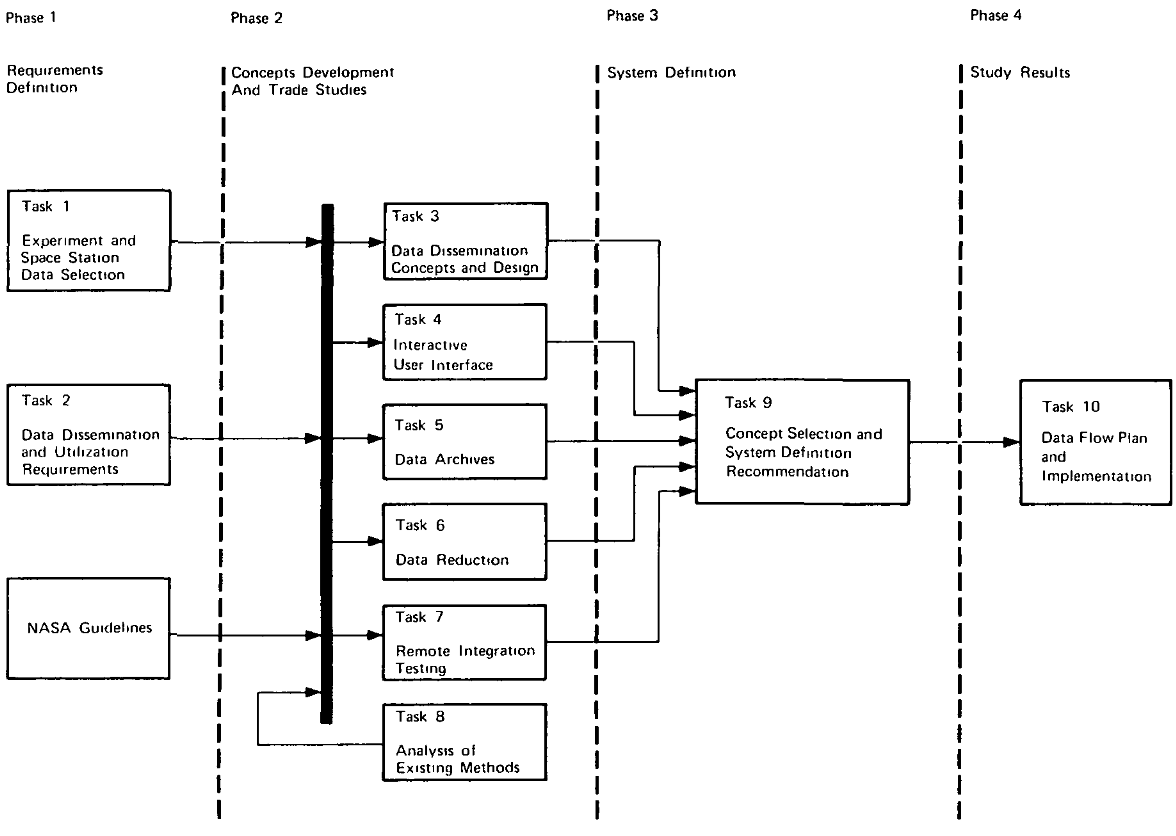


Figure 1. 2-1. Study Task Flow

Phase I consisted of analyzing and defining the requirements on the data handling system Data inputs were derived through analysis of the documents identified previously in 1 1 3 1, guided by a modified form of Case 534G User requirements were arrived at through an extensive series of interviews with users, NASA planning personnel familiar with user requirements and NASA summaries of user requirements on the ERTS and EREP programs

In Phase II, guided by these input and output requirements, and predicting the state-of-the-art in technology for the Space Station time period, subsystem designs were conceptualized

and trade studies done in the areas of dissemination, interaction, archiving, data reduction and remote integration testing Each of these subsystem areas was considered almost independently and trade studies were restricted within the sub discipline This meant that each of the trade studies must be reverified on a total system basis later in the program

Separately in Phase II, existing and planned systems and methods were studied, to determine their applicability to the Space Station experiment program This included sizing existing facilities to handle the processing loads provided by the guideline experiment programs

Phase III consisted of synthesizing an information management system guided by the requirements from Phase I and using the concepts and trade data from Phase II System definition went through a series of iterations involving trades done on an overall system basis

Documentation of the results of the study in a final report and a Data Flow Plan constitute completion of the study as shown in Phase IV

1.3 CONCLUSIONS

Conclusions of the study are summarized in terms of

- System Feasibility, which was first established in Phase II where concepts were sized against the problem
- Baseline System, or the system approach which was presented to and approved by NASA as a viable approach
- Implementation, which represents a final definition of the system and its physical evolution

1.3.1 SYSTEM FEASIBILITY

Feasibility was established on a subsystem basis, initially The conclusions of each of the subsystem studies which have survived the final system definition are described here

1.3.1.1 Requirements

Data requirements dictated by the analysis of Case 534G against the experiment descriptions in the Blue Book are shown in Figure 1 3-1, and Figure 1 3-2

The total data quantities generated and to be handled on a daily basis are shown as about an order of magnitude smaller than previous estimates generated in the early Space Station studies This is attributed to the refinement of experiment definitions as described in the Blue Book These estimates reflect none of the potential effects of interaction or of data compression, which are treated elsewhere Hence they represent a worst case picture of data as received by the ground data handling systems

User requirements analysis yielded a classification of users and a characterization of their requirements These are summarized in Figure 1 3-3

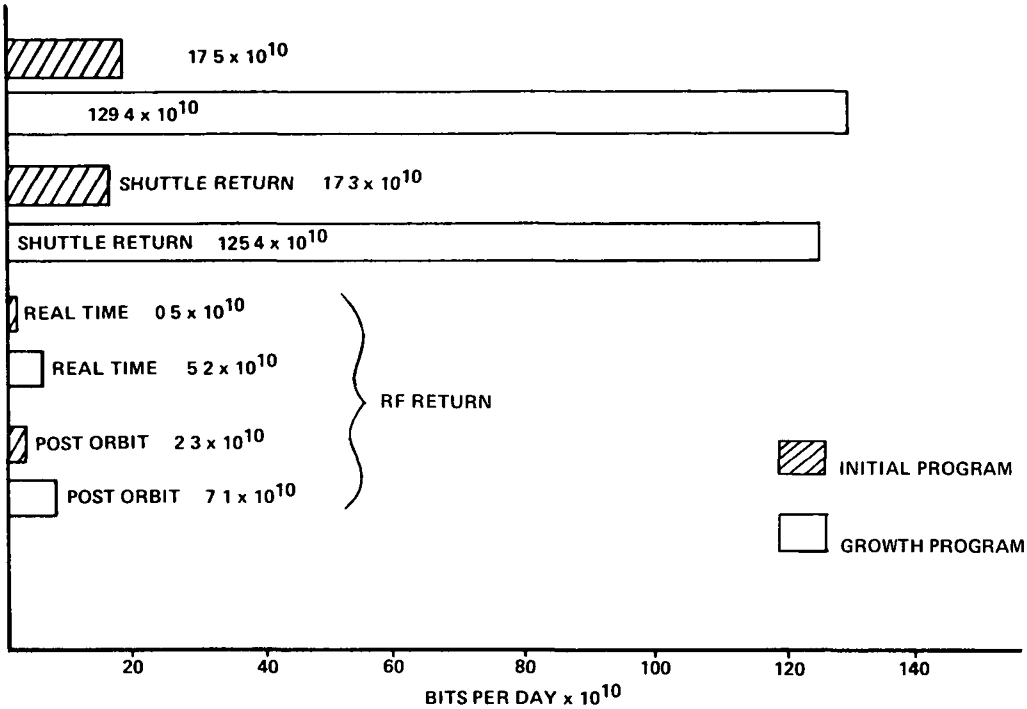


Figure 1. 3-1 Digital Data Distribution Per Day

DATA TYPE	ISS	GSS
DIGITAL	119 REELS OF TAPE	609 REELS OF TAPE
VIDEO	52 REELS OF TAPE	150 REELS OF TAPE
FILM	724 REELS 16 MM 141 CASSETTES 35 MM 261 CASSETTES 70 MM 132 MAGAZINES 240 MM	572 GLASS PLATES 9 CASSETTES 35 MM 141 CASSETTES 70 MM 24 MAGAZINES 240 MM 1 MAGAZINE 150 MM
SAMPLE DATA	MS MATERIALS EMULSIONS SPECIMENS NOTES, LOGS VOICE TAPES, ETC	

Figure 1 3-2 Shuttle Data Return

CATEGORY	PRINCIPAL CHARACTERISTICS	GROUND DATA REQUIREMENT	SPACE DATA REQUIREMENT
EARTH OBSERVATION	• LARGEST USER COMMUNITY • LARGE DATA LOAD • EXTENSIVE DATA PROCESSING • SPECIFIC AREAL AND TIME COVERAGE REQUIRED • TIMELY RESPONSE REQUIRED	• GROUND TRUTH MEASUREMENTS • AIRCRAFT UNDER FLIGHT • METEOROLOGICAL MEASUREMENTS • VERY LARGE	• EXTENSIVE DATA CONSISTING OF PHOTOGRAPHIC IMAGES AND THERMAL SCANNING
TECHNICAL AND ENGINEERING	• GOV'T IS THE PRINCIPAL USER • EXTENSIVE CORRELATION • SMALL DATA COLLECTION ON-BOARD • SIGNIFICANT PHYSICAL DATA • USERS WANT RESULTS NOT DATA	• ENGINEERING AND CONTROL DATA BASE SMALL	• SELECTED TEST POINTS STATUS AND TRENDS • SMALL DATA QUANTITY • SAMPLES AND HARD-WARE RETURNED
SCIENCE	• ORGANIZED USERS (RESEARCH) • HIGH RESOLUTION AND A ACCURACY • NEAR REAL TIME INTERAC-TION EXTENSIVE PREOPERA-TIVE DATA BASE • INTERACTION INITIALLY LARGE	• PHYSICS LOW • ASTRONOMY – LARGE • BIOSCIENCE – MODERATE	• ASTRONOMY-LARGE • BIOSCIENCE-MOD • PHYSICS MOD

Figure 1 3-3. User Requirements Summary

The classifications of Users as shown often involve natural groupings or organizations which have already been established For example, the Kitt Peak Solar Observatory is run by an association of Universities called the Association of Universities for Research in Astronomy, Inc (AURA)

During the extensive user oriented inquiries, an assessment was made of the capabilities available to users in terms of handling the data they will receive from the experiment program This capability is summarized in Figure 1 3-4 Expansion is needed only in the Earth Resources area

1.3.1.2 Data Dissemination

Data dissemination studies revealed that current methods are adequate to meet the dissemination requirements projected in this study No new technology need be developed Although shuttle return of most data was specified or implied in the Blue Book, this was tested by tradeoffs of RF return vs shuttle return with shuttle showing the most practical means of return because of the need to return samples specimens and films, and the limitations in orbit to ground bandwidth

In support of the RF return concept, a trailer mounted receiving/interaction center was defined, and its cost was estimated Its use turned out to be most beneficial when it could communicate directly with the Space Station or experiment carrier rather than via the Tracking and Data Relay Satellite Its best potential may be for overseas data dissemination

DISCIPLINE	CAPABILITY ADEQUATE FOR PROJECTED REQ'TS	TYPE
PHYSICS	YES (2-4 YEARS TURN AROUND)	DIGITAL DATA PROCESSING
ASTRONOMY	YES (2-4 YEARS TURN AROUND)	• SEMI AUTOMATIC ANALYSIS • DIGITAL DATA PROCESSING
LIFE SCIENCES	CAPABILITY ADEQUATE FUNDS REQUIRED	MANUAL SCREENING AUTOMATIC PROCESSING
MATERIALS SCIENCE	YES, PRINCIPAL DATA PROCESSING PERFORMED BY NASA	LABORATORY ANALYSIS AND DIGITAL DATA CORRELATIONS
EARTH RESOURCES – NASA – GOV'T – OTHER	• NO, FACILITIES NEED TO BE EXPANDED • YES, IF FUNDED • NO, CANNOT HANDLE HIGH VOLUME OF DIGITAL DATA	• PHOTO AND DIGITAL DATA PROCESSING • SAME • LARGELY MANUAL INTERPRETATION
TECHNOLOGY	YES, NASA PROCESSES MOST OPERATIONAL DATA	DIGITAL DATA PROCESSING AND TIME/MOTION STUDY
COMMUNICATIONS/NAV	YES	STATISTICAL ANALYSIS AND DATA CORRELATIONS

Figure 1. 3-4. User Capability/In House

The use of National Educational TV (NETV) distribution facilities during off-peak hours, was identified as a means of providing rapid dissemination of data at very low cost on a national basis This comes about because of the heavy United States subsidy of the Public Broadcasting Service through the CPB This offers an avenue for possible further investigation

1.3.1.3 Interaction

This task examined an operational example of the Earth Resources Technology Satellite (ERTS) program and extrapolated the benefits of interaction that might derive from the proposed experiment program Interaction is defined as the coupling of a ground based experimenter into his spaceborne experiments, through electronic means, to approximate his desired control of the experiment The results of this investigation are summarized in Figure 1 3-5 which shows distinct possibilities for reducing data traffic in most disciplines

Assessment of the facilities required to support interaction identified TV down links and voice up link located at a central site (Mission Management)

Benefits occurring from Interaction were identified as follows

- Improved data quality
- Reduced experiment operational time

- Reduced overall data load
- Decreased lag time between data taking and results
- Increased user involvement
- Improved Space Station operational efficiency

DISCIPLINE	REDUCTION FACTOR	PRESENT DATA LOAD	REDUCED DATA LOAD
LIFE SCIENCES	20 1	5 DIGITAL	1 DIGITAL
EARTH RESOURCES	2 1 TO 10 1	8000 DIGITAL	800 TO 4000 DIGITAL
ASTRONOMY	1 1	4 DIGITAL	4 DIGITAL
PHYSICS	4 1	2811 DIGITAL	703 DIGITAL
TECHNOLOGY	2 1	199 DIGITAL 50 VIDEO	100 DIGITAL 25 VIDEO
MATERIAL SCIENCES	10 1	43 DIGITAL 98 VIDEO	5 DIGITAL 10 VIDEO
COMM/NAV	1 1	185 DIGITAL	185 DIGITAL
	TOTAL	11,247 DIGITAL 148 VIDEO	1,798 DIGITAL 35 VIDEO

Figure 1. 3-5. Data Load Reduction Through Interaction

1 3 1.4 Data Reduction

Data processing analyses showed that the preprocessing and common processing projected for the experiment program were well within the limits of feasibility Using expected conventional data processing techniques, computer requirements expressed in instructions per second (IPS) were sized as follows, not including the effects of interaction

- 4 5 X 10^6 IPS for real-time and near real-time data returned through Mission Management for quick reaction and Interaction
- 5 6 X 10^6 IPS for shuttle returned Science and Technology data
- 26 4 X 10^6 IPS for shuttle returned earth resources data

Significant potential for reducing data processing hardware requirements was identified in the following

- Scan Straightener, to convert circular scan data from the Multispectral Scanner to linear scan
- High speed tape I/O, to permit rapid read and write of Ultra High Density (UHD) tapes
- Off-line image read/write

1.3.1.5 Data Archives

Studies of Data Archives resulted in the following significant results

- Technologies currently available are adequate for all archival requirements
- A single catalog should be provided as the key to searching all archives
- Archives should be centralized on the basis of discipline
- 45 day storage must be provided to support Mission Management and Interaction

With a postulated set of users, and a purging schedule based on user requirements, the size of the data base is maintained reasonable Since much of the data is stored on Ultra High Density (UHD) tape, in the form in which it is received, physical space requirements are modest For example, all experiment data accumulated over a 15 year period can be contained in a storage area of 252 square meters (2800 square feet)

1.3 1.6 Existing Systems

NASA presently maintains a powerful set of data handling facilities easily capable of handling all payload data except Earth Resources When it is realized that these facilities currently support all present space experiment programs, it is not surprising that with selected upgrading these facilities can handle the projected data load The selected upgrading takes into consideration a normal evolution expected during the 1970's such as the replacements of computers with more recent versions with greater data handling capability at a lesser cost per bit

Planned capabilities are not overlooked, and it is expected that the present Earth Resources development programs at each of the centers will continue to bring the data handling problems in this application area under control, in several ways

- development of techniques in solving Earth Resources problems
- development of facilities which could be phased into the overall Earth Resources Management program on an operational service basis For example, the Hybrid facilities at MSC See Section 8 3 4, Earth Resources Image Processing System
- development of technologies for onboard or ground use

Of particular note in the last category is the Optical Processing Program currently on-going at MSFC This program has demonstrated the feasibility of storage and correlation techniques

that have the potential to make the greatest single contribution to the problem of handling data in the experiment program

1.3.1.7 Remote Integration Testing

This task examined alternative concepts for integration of new experiments into an already orbiting Space Station, recommending that two be retained for further consideration

- Final integration testing be accomplished on the ground, in the vehicle to be orbited when this is feasible
- Factory checkout suffice for establishing confidence when the experiment to be integrated is not complex

1.3.2 BASELINE SYSTEM

A recommended Baseline System Approach was jointly agreed upon between NASA and IBM, and is summarized here

1.3.2.1 Baseline Responsibilities

Responsibilities in the baseline concept are as follows

- NASA should perform initial data handling functions
  - Receiving data
  - Organizing data
  - Duplicating and delivering data
- NASA should perform vehicle and mission management functions
  - Prelaunch, launch, and operations supervision
  - Experimenter interaction
- NASA should maintain control and traceability of data
  - Centralized catalog
  - Entry management
- Government organizations and facilities should be used to provide needed capacity for data processing
  - Follow lines of existing responsibility
  - More involvement of existing user groups
  - Discipline oriented distribution

1.3.2.2 Work Load Distribution

The Baseline Concept suggests assignment of responsibilities, primarily in the basic science and technical areas, to several NASA centers in accordance with their available capabilities Figure 1 3-6 shows the recommended discipline oriented processing responsibilities

FACILITY	RESPONSIBILITY	REQUIREMENT	CAPABILITY
MSFC/ SLIDELL	MS/MS TECHNOLOGY COM/NAV	12 4 x 10^{10} BITS/MONTH 3000 IMAGES/MONTH 3 3 MHZ VIDEO	57 x 10^{10} BITS/MONTH 4300 IMAGES HAS VIDEO
GSFC	PHYSICS	30 x 10^{10} BITS/MONTH 16 MM MOVIE FILM 33 MHZ VIDEO 835 IMAGES	12 x 10^{10} BITS/MONTH (REQUIRES EXPANSION) HAS VIDEO HAS FILM 40K IMAGES/MONTH
MSC	LIFE SCIENCES	1 8 x 10^9 BITS/MONTH 4 MHZ VIDEO 35 MM MOVIE 1000 FRAMES 70 MM SAMPLES	30 x 10^9 BITS/MONTH HAS VIDEO CAPABILITY HAS FILM CAPABILITY HAS SAMPLING CAP- ABILITY

Figure 1. 3-6 Existing Facility Utilization

1.3.2.3 Earth Resources Information Management

In the Baseline System proposed, sizing and distribution of the system for handling Earth Resources data were derived to the extent of recommending guidelines as follows

- Follow natural lines of agency responsibility in assigning roles
- Augment the Lewis Research Center data catalog to list data pertaining to all disciplines
- Recognize other government agency plans for facilities Of particular note here is the Department of Interior Data Center currently being implemented at Sioux Falls, South Dakota

1.3.3 SYSTEM IMPLEMENTATION

The end result of this study is a system configuration as summarized in Figure 1 3-7, Data Flow System Final recommendations for allocation of responsibilities and functions are summarized in the following paragraphs

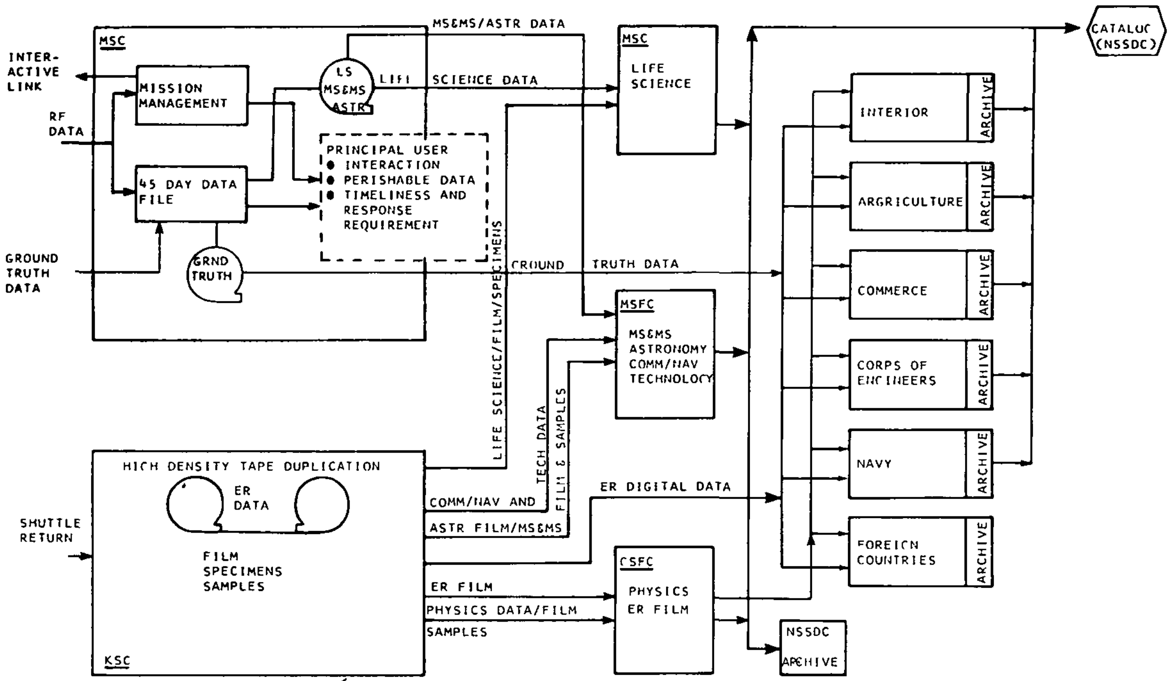


Figure 1. 3-7. Data Flow System

1.3.3.1 MSC Functions

RF data is returned to MSC This includes perishable data and data required for interaction Perishable data is routed to the user for his immediate use Interaction data is used for real time or near real time management of the experiment mission. Interaction consoles are provided, where users or agents can have TV coverage of the experiment, voice contact, and graphic display of experiment data In the case of Materials Science and Manufacturing in Space (MS/MS), console facilities are remoted to MSFC, where a control experiment may be run simultaneously

Mission management conducted from the MSC location differs from the traditional mission control in that it plans, schedules and monitors the experiment program The Space Station and Shuttle are relatively autonomous vehicles

The 45 day data file maintains a data base between shuttle visits, for Mission Management and Interaction.

Data Processing for Life Sciences experiments is done at MSC and data is routed to National Space Science Data Center (NSSDC) at Goddard for archiving

1.3.3.2 KSC Functions

Shuttle launch and return are handled at KSC Consequently the initial data collection function for shuttle return is done here including offloading, classifying, high density tape reproduction for Earth Resources data, and shipping to data centers for processing

1.3 3.3 MSFC Functions

Processing is provided by MSFC for

- MS/MS
- Astronomy
- Comm /Nav
- Technology

Data is archived at NSSDC

MSFC also provides the remote facilities for the experimenter to interact with his experiments, including the Interaction Console

1.3.3.4 GSFC Functions

Processing of Physics data is done at GSFC Archiving of all non-Earth Resources data is at NSSDC

1 3.3.5 Other Agency Functions

Each of the Data Centers shown, provides both data processing and archiving for its set of users Each center receives all Earth Resources data, but since it serves a different set of users it performs a different set of functions on the data. Data processing capability at each of these centers should be able to perform some degree of special processing for users

1.3 3.6 Catalog Functions

A single catalog which serves as the entry point to a search for experiment data is assumed, for planning purposes, to be at NSSDC, colocated with the archives for cost effectiveness

Abstracting and indexing are done at all data centers or under their control and entires are made into the catalog when data is archived

Remote terminals, to permit interactive inquiry with the catalog, are provided at all data centers and certain other key locations

1 4 RECOMMENDATIONS

Full implementation of a data flow system for space experiment data requires continuous and more detailed planning than has taken place in this study Certain key recommendations, in this context, are identified in this section

1 4 1 NASA CONTROL OF DATA

Information is the purpose of the experiment program Information Management is therefore the single most important responsibility in the program This management responsibility

extends from experiment definition through the extraction of information from experiment data and should influence all program phases, from design through test operation and data analysis

Unless and until another agency is fully authorized and organized to do so, NASA should maintain full Information Management responsibility

1.4.2 NASA SUPPORT OF TECHNOLOGY DEVELOPMENTS

NASA should support the development of technologies which promise to improve the feasibility and economy of handling the experiment program data and information This does not necessarily imply financing The following technologies are included

- UHD tape computer input/output
- Scan straightener
- Optical processing techniques and technology
- Space-borne tape recorder alternatives

1.4.3 NASA PROMOTION OF ITS DATA PRODUCTS IN APPLICATION AREAS

Each of the major NASA locations is currently developing applications of remote sensing to land use or other timely problems in its local area This work, which is going on in cooperation with local government agencies has the capacity for stimulating the interest of the public with the resulting potential of public support for Earth observation programs and the discovery of additional timely applications

1.4.4 NASA/OTHER AGENCY DEVELOPMENT OF INTERFACE AND CONTROL METHODS

The Earth Resources Survey Program Requirements Committee has done a commendable task in establishing agency positions in the Earth Resources Survey Program These efforts should be continued in order to better define roles, and, in particular, to agree upon methods of interface between agencies, transfer of data, and control of information

1.4.5 NASA DEVELOPMENT OF REGIONAL DATA CENTERS

This study has recommended a system in which NASA performs initial data handling and common processing, and in which special analytical processes are performed by the user, or by a data center for a user NASA is presently developing analytical techniques which may be employed by the users The possibility of developing regional centers employing these techniques for servicing users is recommended for exploration for the following reasons

- NASA has a start at the present time
- Cooperative developments among present NASA facilities is easily manageable
- The resulting insight into user problems is invaluable to Information Management

1.4 6 CONTINUED STUDY

Continued study is recommended in the following areas

- Analysis in greater depth of a specific shuttle mission with the following advantages

  (a) Better sensor definition

  (b) More specific user requirements

  (c) Nearer potential implementation

- Interaction techniques A penetrating analysis of specific user problems conducted in cooperation with the users Possible multiphase program involving simulation and real-time test using presently operating aircraft programs

- Incorporation of foreign users into the system

REQUIREMENTS ANALYSIS 2

2.1 INTRODUCTION

Data acquired from spaceborne sensor systems can easily inundate the potential users – as well as the collecting systems – unless some attempt is made to confine the acquisition of data by a well defined and continually refined set of requirements

Potential Users of data have problems in the scientific and applications areas that have been expressed as sensors and operations for observing and data quantities that represent observations that impose, at least, the first cut requirements that a system of data flows must meet This section addresses the requirements of both the systems and the Users to define and refine requirements in the interest of flowing the maximum amount of information using the least amount of data

Data Flow system requirements discussed in this section are based on

- sensor system characteristics
- experiment objectives
- User data and interaction needs

Each of these is considered operationally to add the flavor and meaning of a dynamic data stream that responds in a timely manner to realistic needs, that reacts to real life decisions, that recognizes real life system and User limitations

2.1.1 SENSOR SYSTEM CHARACTERISTICS

Accommodation of ground data flow is sensitive to the fixed characteristics of the sensors used in the experiment packages Both the facilities and the support functions implemented, as well as the system loading, depend on the information format, that is, whether information is gathered in the form of samples, photographic film or digital data, and the rate and bandwidth required by the data for transmission fidelity Most experiments require system data that defines the conditions or environment under which the data were taken Examples of this data are pointing information, sensor stabilization, and operational evaluation provided by the onboard experiment Also, correlary data for control and calibration is generated by ground based instrumentation or sensors flown in aircraft over a ground control site Both the ground truth data and the aircraft gathered data must be correlated with the experiment sensor system data before a meaningful analysis can be made Table 2 1-1 summarizes the characteristics of sensor systems that affect data handling

2.1.2 EXPERIMENT OBJECTIVES

The quantity and quality of data generated in support of an experiment program are established in part by the experiment objectives See Table 2 1-2 The areal coverage and the resolution required determine the quantity of data required for each identified target The requirement for accuracy will establish the degree to which ground truth or baseline sensor data (aircraft gathered) will be needed Data quantity is also affected by the frequency and the duration of observation For example, in agriculture, measurements are required at least quarterly so that a complete growing cycle can be observed

Table 2. 1-1. Sensor System Characteristics

INFORMATION FORMAT
Sample
Film
Image, Spectra, Etc
DATA BANDWIDTH
Sample Rate
SUPPORT SYSTEM ACCURACY
Pointing
Stabilization
Maneuvers
ANCILLIARY INFORMATION
Ground Truth
Control Support
Calibration

Selection of sensors can have a major impact on the data flow Film camera systems cannot provide target data for evaluation or interaction, for example. Since each sensor or sensor type has been specified or selected to meet specific experiment objectives, the data system will be required to accept all data forms

Table 2. 1-2. Data Flow Aspects of Experiment Objectives

- Areal Coverage
- Resolution
- Accuracy
- Observation Frequency and Repeat Requirements
- Observation Duration
- Sensor Grouping

2.1.3 USER NEEDS

The user needs determine the form and timeliness of data products delivered by the data flow system in two respects First is the need for visibility during the experiment operation and the second is the need for data to support scientific or application analysis In the first cast, response delays keyed to the user needs determine system implementation The need for quick-look or real time data and the fidelity with which data must be presented size the RF downlink over which operational data is communicated The need for influencing or interacting with onboard operations establishes a need for data or signal uplink capability In support of these two very important system aspects, as well as supporting the analytical effort to follow, there is a requirement for preprocessing large amounts of data The degree to which data is preprocessed and exactly where the processing will take place is a function of trade studies discussed in Section 5

The analytical techniques used, determine the form of the ground data flow system output product Data must be delivered to the user in a form consistent with the user's processing procedures and techniques These may be either computer compatible magnetic tapes, photographic film, or in some cases semi-processed data in the form of isoplethic maps showing plots of parameters of interest Consideration of the user needs and impacts on the ground data flow system are listed in Table 2.1-3

Table 2 1-3. User Needs

• Response Delays	– RF Versus Bring Back
• Quick-Look Fidelity	– High Resolution Versus Low Resolution
• Interaction Capability	– Data Needs and Flexibility
• Preprocessing	– Quantity and Quality
• Usable Data Forms	– Magnetic Tapes

The following sections will present various hardware and program aspects of the mission in order to build a mission model against which system capabilities can be specified Section 2 2 will present the mission and hardware aspects of data generation, Section 2 3 will identify the onboard data handling as it interfaces with the ground system, and Section 2 4 will identify the requirements imposed on the system by data use

2.2 MISSION BASELINE

2.2.1 EXPERIMENT SCHEDULES

The experiment program chosen as a model for the data flow analysis is similar to the experiment program defined by McDonnell Douglas Company for the Phase B Space Station study

Case 534G, shown in Figure 2 2-1, represents the results of a number of scheduling exercises that considered not only the experiments and their physical characteristics but also the availability of resources onboard the Space Station necessary to support the objectives of the experiment The material extracted from the Space Station study consisted of an initiation

date and duration for each experiment and the time-line recommended for experiment operation The latter document is a product of Martin Marietta Company The NASA Blue Book was the basis for both of these documents and became also a baseline document for the data flow study

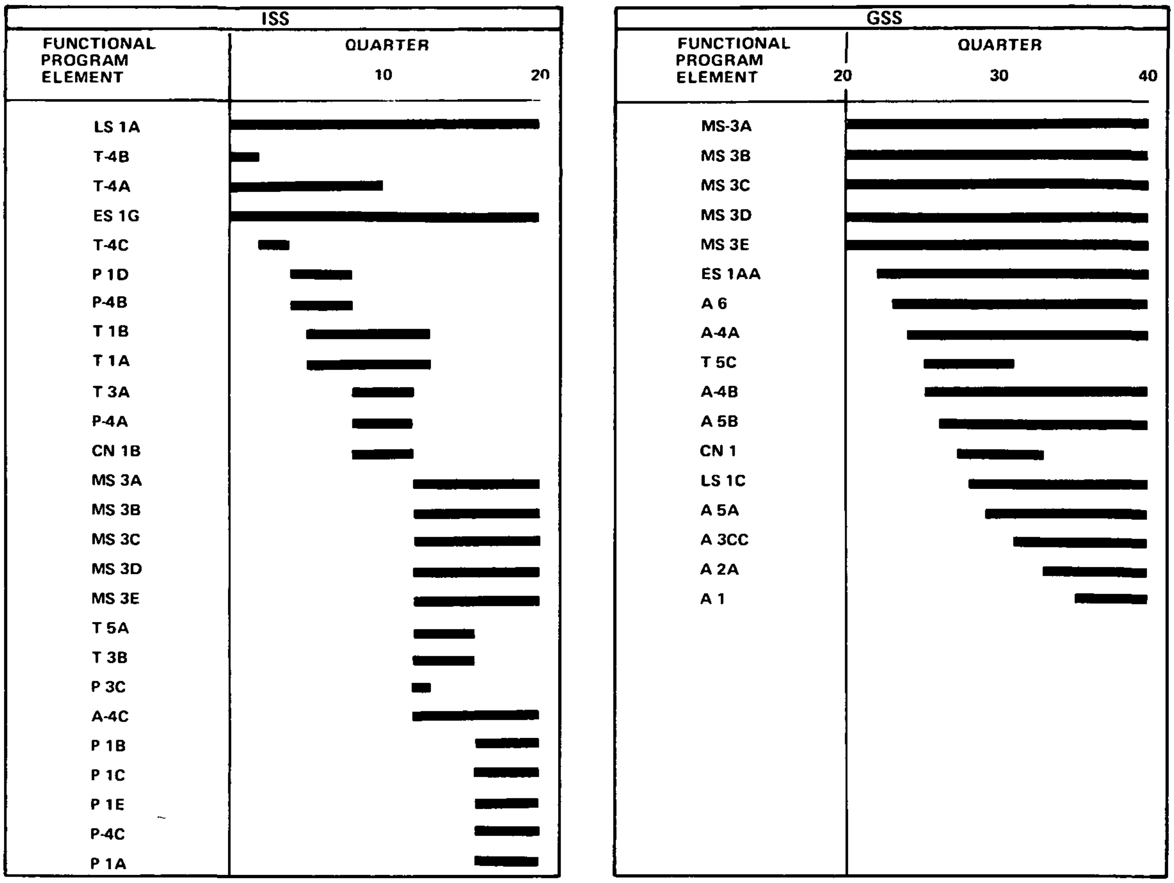


Figure 2 2-1. Experiment Case 534G

Some modifications were made to the basic 534G schedule, as shown, to include experiments of special interest that were not included in the original 534G and to establish two points for design, the first being the Initial Space Station (ISS) and the second being the Growth Space Station (GSS) In selecting an experiment schedule for the data flow study, no attempt was made to optimize operations, cost or experiment program characteristics The intent was merely to define an experiment model that would be typical of the time frame, to facilitate the definition of ground systems required for data flow support.

A considerable amount of preliminary analysis was required to go beyond the space station study treatment of experiment scheduling to obtain operational details at a level sufficiently low that support parameters could be identified. The original schedule showed only mission quarters during which each experiment would be operated Study needs necessitated a more detailed operational definition to identify specific time-lined data flow The baseline schedule was expanded to show experiment operation for two mission quarters (one each in ISS and GSS) Several factors become evident as shown in Figure 2.2-2 When the experiment schedule

is viewed on this scale, the effects of scheduling operations becomes evident The continuous operation implied by the ten year schedule (Case 534G) is seen realistically as periodic duty cycles not requiring continuous support The quarterly schedule also shows four days each month reserved for logistics arrival No experiments are operated during this time (with the possible exception of some physics and exposure experiments that require little or no crew participation) due to vehicle perturbation and crew involvement in resupply

As schedules are developed to smaller time slices, the major difference between ISS and GSS also becomes evident The simpler experiments selected for the earlier time period do not operate as long nor as continuously as the more sophisticated experiments selected for GSS

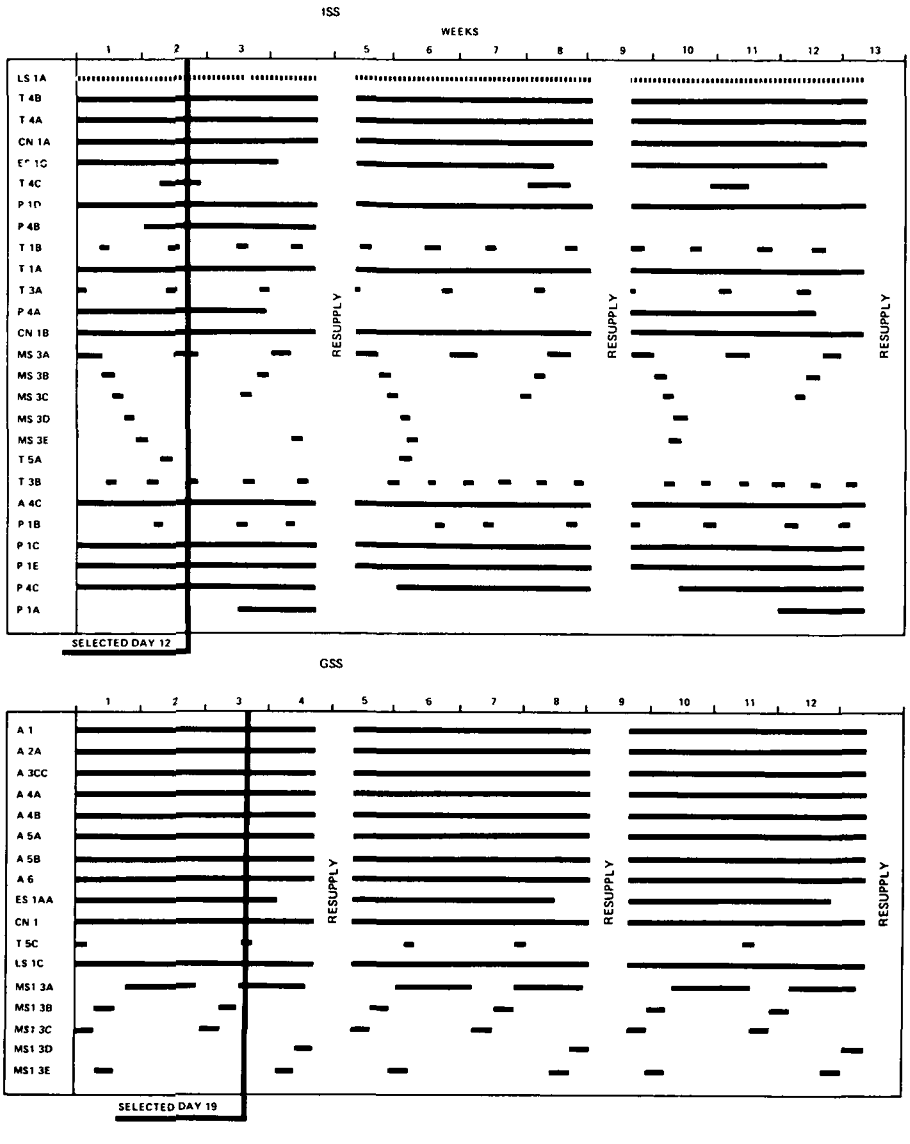


Figure 2. 2-2. Quarterly Schedule, ISS and GSS

A specific day was chosen from the quarterly schedule for further expansion. The day selected was picked on the basis of data generated to represent a "heavy duty" day. The expansion of day 12 for ISS and day 19 of GSS are shown in Figure 2 2-3 As expected, only 15 of the 26 experiments originally scheduled during the quarter are scheduled on the selected day for ISS For GSS, 13 of the original 17 appear during the selected day

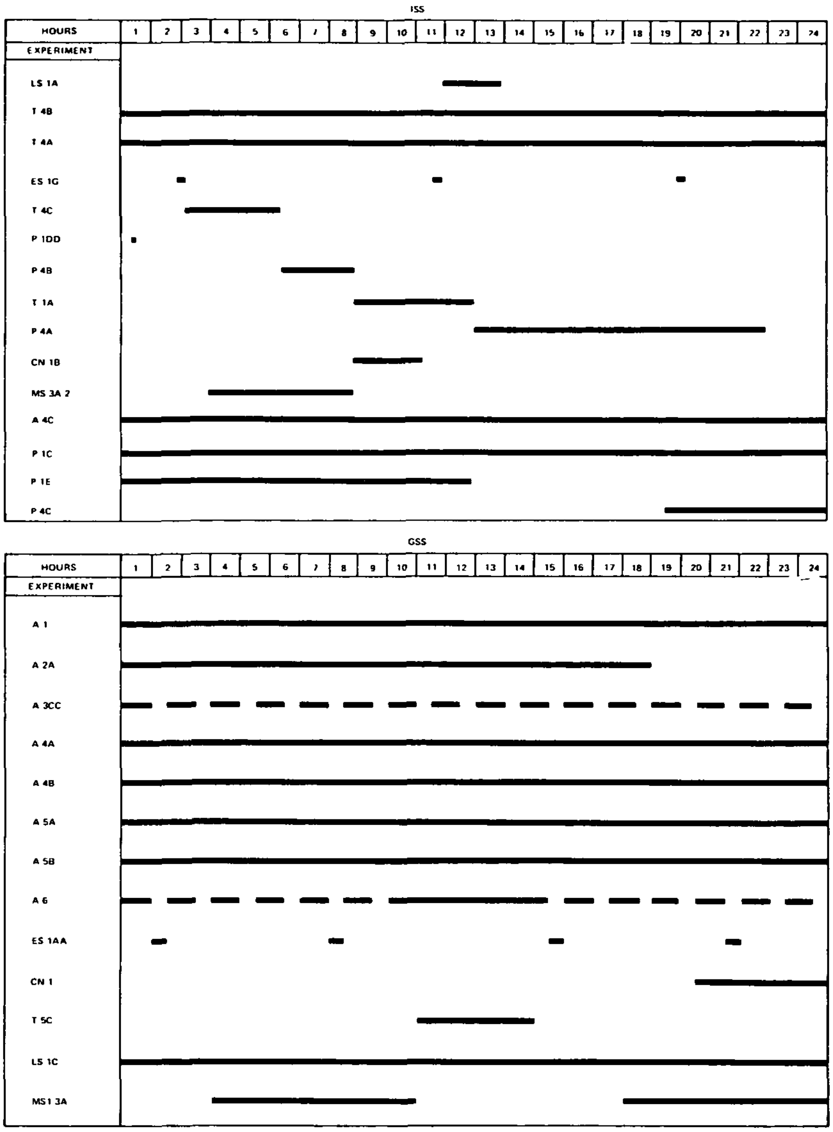


Figure 2. 2-3. Selected Daily Schedules

The daily schedule provides the basis for an operational analysis to determine time phased support This information combined with onboard hardware and experiment characteristics will define data flow support

2.2.2 EXPERIMENT DATA CHARACTERISTICS

Experiment data forms, i e , digital, analog, film samples, etc , are established when the sensor and sensor systems are chosen The experiment objectives play an important part in the selection and also determine the rates at which observations are made, samples are taken or scans are made

Each of the experiments identified by the operating schedule (Case 534G) was analyzed and the support characteristics identified The characteristics are shown in Figure 2.2-4 for ISS and 2 2-5 for GSS Significant features that have been identified include

Data Rate	– Each sensor system has a rate associated with it that matches either the rate of change of the phenomena being observed or selected to give a desired data overlap
Daily Data Quantity	– The number of targets or observations made in a day determines the quantity (frames, samples, bits per day or hours per day of video) quantity of data collected during a day
Real Time Transmission Requirement	– A percentage of the data collected is needed on the ground quickly to provide either operational visibility or the rapid use of perishable data Interaction with ongoing experiments depends on timely data
One Orbit Delayed Requirement and 1-7 Day Delayed Requirement	– Operational evaluation and experiment or procedural verification can usually be determined analyzing data off-line The change does not require real time data but does require data within days Some of the perishable data also falls into this category
Recorded for Return	– In general, all data is recorded for return Even the data that is transmitted is recorded Exceptions are the experiments that have all data transmitted
Total Shuttle Return Bits and Video	– The daily recorded data accumulates on the space vehicle until the monthly shuttle resupply The data numbers shown in this column represents the monthly volume of data generated by each experiment
Film Data	– The rates and accumulation are listed for data being recorded on photographic film and plates

The detailed description of experiments and sub-experiments are contained in Appendix A

2.3 REFERENCE VEHICLE DATA MANAGEMENT SYSTEM CAPABILITY

The ground data handling system interfaces closely with, and is significantly influenced by, the functional design and implementation of the onboard data system This section will describe the onboard data system as a point of departure for the ground data system

		Electronic Data								Film Data	
		Data Rate	Daily Data Quantity	Real Time Trans Req't	1 Orbit Delayed Requirement	1-7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
LS 1A	Minimum Medical Research Facil	Video 4MHz 12 KBPS 2 KBPS	On Demand 7 x 10^7 BPD	1 Hour None	7 0 x 10^7 BPD	None None	None None	None	None	7,255	188,530
T-4B	Medium Duration System Test	600 BPS	5 18 x 10^7 BPD	None	None	2 6 x 10^7 BPD	5 18 x 10^7	13 5 x 10^8	None	20	520
T-4A	Long Duration System Test	1 0 KBPS	8 64 x 10^7 BPD	None	None	8 64 x 10^6 BPD	8 64 x 10^7	22 5 x 10^8	None	None	None
ES 1G	Earth Observations (Min Payload)	50 MBPS	1 35 x 10^{11}	1 35 x 10^9	6 75 x 10^9 BPD	1 35 x 10^{10} BPD	1 35 x 10^{11}	29 7 x 10^{11}	None	1620	35,640
T 4C	Short Duration System Test	460 KBPS	5 6 x 10^9 BPD	None	None	2 8 x 10^9 BPD	5 6 x 10^9	22 4 x 10^9	None	19,200	76,800
P 1D	Thick Meteoroid Penetration	2K BITS/SCAN	2 KBPD	None	None	None	2 KBPD	52 x 10^3	None	None	None
P 4B	Flame Chemistry & Laser Experiment	2 4 x 10^6 BPS	21 6 x 10^9 BPD	2 1 x 10^8 BPD	None	None	21.6 x 10^9	432 x 10^9	None	7500	150,000
T 1B	Contamination Monitoring	20 4 KBPS	4 8 x 10^7 BPD	4 8 x 10^6 BPD	None	None	4 8 x 10^7	19.2 x 10^7	None	None	None
T 1A	Contamination Measurements	10 MHz 20 4 KBPS	55 Min/Day 5 87 x 10^8 BPD	5 Min/Day 5 87 x 10^7 BPD	None	None	55 min/Day 5 87 x 10^8	153 4 x 10^8	23 5 hr	370	9,600

Figure 2.2-4 (1). ISS Experiment Data Characteristics Summary

	Electronic Data								Film Data	
	Data Rate	Daily Data Quantity	Real-Time Trans Req't	1 Orbit Delayed Requirement	1 7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
T-3A Astronaut Maneuvering Unit	5 KBPS Video 3 MHz Voice - 4 KHz	5 4 x 10^7 BPD 180 min/day 180 min/day	5 4 x 10^6 None None	None None None	None None None	5 4 x 10^7 180 min/day 180 min/day	1 6 x 10^8	3MH - 27 Hr 4KHz - 27 Hr Voice	14 400	129 600
P-4A Airlock & Boom Experiments	45 KBPS	1 62 x 10^9 BPD	1 62 x 10^8 BPD	None	None	1 62 x 10^9 BPD	3 40 x 10^{10}	None	None	None
CN-1B Comm/Nav Research Group	300 KBPS	2 6 x 10^9 BPD	5 2 x 10^8 BPD	None	None	2 6 x 10^9	6 8 x 10^{10}	None	330	8580
MS 3A 1 Crystal Growth From Solution	10^4 BPS 3 3 MHz	28 8 x 10^7 BPD 420 min/day	2 88 x 10^7 BPD 1 hr/day	None 6 hrs/day	25 9 x 10^7 BPD None	None None	None	None	None	None
MS-3A 2 Crystal Growth From Melt	10^4 BPS 3 3 MHz	18 x 10^7 BPD 6 hrs/day	2 7 x 10^7 BPD 2 hrs/day	None 4 hrs/day	15 3 x 10^7 BPD None	None None	None	None	None	None
MS 3A 3 Biological Separation	10^4 BPS 3 3 MHz	4 32 x 10^8 BPD 14 hrs/day	4 32 x 10^7 BPD 2 hrs/day	None 12 hrs/day	3 9 x 10^8 BPD None	None None				

Figure 2.2-4 (2). ISS Experiment Data Characteristics Summary

	Electronic Data								Film Data	
	Data Rate	Daily Data Quantity	Real Time Trans Req't	1 Orbit Delayed Requirement	1 7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
MS 3A 4 Preservation of Biochemicals	10^4 BPS 3 3 MHz	2 16 x 10^8 4 hr/day	0 54 x 10^8 BPD None	1 64 x 10^8 BPD 4 hrs	None None	None None	None	None	None	None
MS-3A 5 Physical Processes In Fluids	10^4 BPS 3 3 MHz	4 32 x 10^8 4 hrs/day	2 16 x 10^8 BPD None	None 4 hrs/day	2 16 x 10^8 BPD None	None None	None	None	None	None
MS 3B 1 Crystal Growth From Vapor	10^4 BPS 3 3 MHz	21 6 x 10^7 BPD 6 hrs/day	2 16 x 10^7 BPD None	None 6 hrs/day	19 4 x 10^7 BPD None	None None	None	None	None	None
MS 3B 2 Free Casting of Metals	10^4 BPS 3 3 MHz	10 8 x 10^7 BPD 3 0 hrs/day	2 7 x 10^7 BPD 1 hr	None 2 hrs	8 1 x 10^7 BPD None	None None	None	None	None	None
MS 3C 1 Metal Matrix Composites	10^2 BPS 3 3 MHz	21 6 x 10^5 6 hr/day	3 2 x 10^5 BPD 2 hr/day	None 4 hr/day	18 4 x 10^5 None	None None	None	None	None	None
MS 3C 2 Controlled Density Materials	10^2 BPS 3 3 MHz	18 x 10^5 BPD 8 hr/day	9 x 10^5 BPD 2 hr/day	None 6 hr/day	9 x 10^5 BPD None	None None	None	None	None	None

Figure 2.2-4 (3). ISS Experiment Data Characteristics Summary

	Electronic Data								Film Data	
	Data Rate	Daily Data Quantity	Real Time Trans Req't	1 Orbit Delayed Requirement	1 7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
MS 3C-3 Preparation of Glasses	10^5 BPS 3 3 MHz	21 6 x 10^8 BPD 5 hrs/day	2 16 x 10^8 BPD 2 hr/day	None 3 hrs/day	1 94 x 10^8 BPD None	None None	None	None	None	None
MS-3D 1 Liquid Dispersion	10^2 BPS 3 3 MHz	14 4 x 10^5 BPD 4 hrs/day	2 16 x 10^5 BPD 1 hr/day	None 3 hr/day	12 2 x 10^5 BPD None	None None	None	None	None	None
MS-3D 2Glass Processing	10^5 BPS 3 3 MHz	21 6 x 10^8 BPD 6 hr/day	2 1 x 10^8 (10^4 BPS) 2 hr/day	None 4 hr/day	19 44 x 10^8 BPD None	None None	None	None	None	None
MS 3E 1 Supercooling and Homegeneous Nucleation	10^4 BPS 3 3 MHz	73 8 x 10^7 BPD 8 hrs/day	7 3 x 10^7 BPD 1 hr/day	66 42 x 10^7 BPD 7 hrs/day	None None	None None	None	None	None	None
T 5A Teleoperations Initial Flight	730 BPS 8 4 MHz	21 0 x 10^6 BPD 6 hrs/day	None None	None None	None None	21 x 10^6 BPD 8 4 MHz 6 hr	21 x 10^6 BPD	8 4 MHz 6 hr	None	None
T 3B Maneuverable Work Platform	8 KBPS 3 MHz	8 64 x 10^7 BPD 3 hours	None None	None None	None None	8 64 x 10^7 BPD	60 5 x 10^7	3 MHz 21 hr	18,000	126 000
P 3C Plastic Emulsions	Emulsion	2 sheet/month	— — —	— — —	— — —	2 sheet/month*	— — —	— — —	— — —	— — —

*No digital data

Figure 2.2-4 (4). ISS Experiment Data Characteristics Summary

		Electronic Data								Film Data	
		Data Rate	Daily Data Quantity	Real Time Trans Req't	1 Orbit Delayed Requirement	1 7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
P-1B	Cometary Physics	20 KBPS	$7\ 2 \times 10^7$ BP Event	None	None	None	$7\ 2 \times 10^7$ Bits/ Event*	$21\ 6 \times 10^7$	None	None	None
P 1C	Meteoroid Science	312 Bits/Event	31200 BPD	None	None	None	31200 BPD**	$8\ 11 \times 10^5$	None	2	5
P-1E	Small Astronomy Telescopes	120 K Bits/Sec	$5\ 2 \times 10^9$ BPD	$5\ 2 \times 10^8$ BPD	None	None	$5\ 2 \times 10^9$ BPD	$13\ 52 \times 10^{10}$	None	30	780
P 4C	Test Chamber Experiment	65 KBPS	130×10^7 BPD	None	None	None	130×10^7 BPD	$2\ 73 \times 10^{10}$	None	59,424	$1\ 248 \times 10^6$
P 1A	Atmospheric and Magnetoscience Mode 1	150 KBPS 330 KHz	10% $12\ 9 \times 10^9$ BPD 24 hr/day	None None	None None	None None	$12\ 9 \times 10^9$ BPD 24 hrs/day	$10\ 32 \times 10^{10}$	330 KHz 192 hr	None	None
	Mode 2	150 KBPS 330 KHz	$1\ 62 \times 10^9$ BPD 3 hrs/Day	None None	None None	None None					
A-4C	Small UV Survey Telescopes	500 BPS 2 9 MHz	$4\ 3 \times 10^7$ BPD 1 1 hr/day	$4\ 3 \times 10^7$ BPD 1 1 hr/day	None Non	None None	None None	None	None	96	2496

*≈ 10 events/year
**≈100 events/day

Figure 2.2-4 (5) ISS Experiment Data Characteristics Summary

	Electronic Data								Film Data	
	Data Rate	Daily Data Quantity	Real-Time Trans Req t	1 Orbit Delayed Requirement	1-7 Day Delayed Requirement	Recorded For Return	Total Bits Shuttle Return	Total Video Shuttle Return	Frames Per Day	Total Frames Shuttle Return
A-1 X-Ray Stellar Astronomy	4 8 x 10^4 BPS	1 45 x 10^9 BPD	1 45 x 10^7 BPD	None	None	1 45 x 10^9 BPD	37 7 x 10^9	None	None	None
A-2A Intermediate Stellar Telescope	1 2 x 10^7 BPS	3 75 x 10^8 BPD	5 63 x 10^7 BPD	None	None	3 75 x 10^8 BPD	97 5 x 10^8	None	22	572 - 10"x 10" Glass Plates
A-3CC ATM Follow-On	9 5 x 10^6 BPS 2 9 MHz 3 3 MHz	4 54 x 10^{11} BPD 164 Min 800 Min	2 9 MHz 164 Min 3 3 MHz 80 Min	None	None	4 54 x 10^{11} BPD 3 3 MHz 800 Min	63 44 x 10^8	3 3 MHz - 376 7 Hrs	None	None
A-4A C-9M Narrow Field UV Telescope	8 6 x 10^6 BPS 400 KHz	4 66 x 10^{10} BPD 96 Min	4 6 x 10^9 BPD	None	6 65 x 10^8 BPD	4 6 x 10^{10} 400 KHz 96 Min	119 6 x 10^{10}	4 MHz - 41 6 Hrs	96	2496
A-4B C-3M Wide Field UV Telescope	2 8 x 10^6 BPS	1 09 x 10^9 BPD	1 09 x 10^7 BPD	None	1 09 x 10^9 BPD	None	None	None	5	130
A-5A X-Ray Telescope	7 x 10^6 BPS (2%) 11 1 KBPS (100%)	1 33 x 10^{10} BPD	1 33 x 10^{10} BPD	None	None	9 7 x 10^8	25 2 x 10^9	None	None	None
A-5B Gamma Ray Telescope	7 x 10^6 BPS (2%) 11 9 KBPS (100%)	131 4 x 10^8 BPD	1 22 x 10^{10} BPD	None	None	10 4 x 10^8	27 0 x 10^9	None	None	None
A-6 IR Telescope	7 x 10^6 BPS 11 MHz	68 5 x 10^9 BPD 2 7 Hrs	6 8 x 10^9 BPD 11 MHz 2 7 Hrs	None	None	68 5 x 10^9 BPD	17 80 x 10^{11}	None	None	None
ES-1AA Earth Observation Sequential	51 3 MBPS	1 85 x 10^{11} BPD 2782 FPD	1 85 x 10^{10} BPD	1 85 x 10^{10} BPD	5 55 x 10^{10} BPD	1 85 x 10^{11} BPD 2782 FPD	40 7 x 10^{11}	None	2782	58428
CN-1 Communications Navigations Facility	300 KBPS	3 3 x 10^6 BPD	0 66 x 10^6 BPD	None	None	3 3 x 10^6 BPD	83 6 x 10^6	None	30	780
T-5C Ground Control Teleoperator	4 9 KBS 8 4 MHz	3 5 x 10^7 BPD 2 Hrs 18 Day	8 4 MHz 2 Hr 18 Day	None	None	3 5 x 10^7 BPD	7 0 x 10^7	None	None	None
LS-1C Intermediate Life Science Research Facility	3 KBPS 4 MHz	25 9 x 10^7 BPD 2 Hrs	4 MHz 2 Hrs	25 9 x 10^7 BPD	None	None	None	None	None	None
MS-3A-1 Crystal Growth From Solution	10^4 BPS 3 3 MHz	28 8 x 10^7 BPD 7 Hrs Day	2 88 x 10^7 BPD 1 Hrs Day	None 6 Hrs Day	25 9 x 10^7 BPD None	None	None	None	None	None
MS-3A-2 Crystal Growth From Melt	10^4 BPS 3 3 MHz	18 x 10^7 BPD 6 Hrs Day	2 7 x 10^7 BPD 2 Hrs Day	None 4 Hrs Day	15 3 x 10^7 BPD None	None None	None	None	None	None
MS-3A-3 Biological Separation	10^4 BPS 3 3 MHz	4 32 x 10^8 BPD 14 Hrs Day	4 32 x 10^7 BPD 2 Hrs Day	None 12 Hrs Day	3 9 x 10^8 BPD None	None None	None	None	None	None
MS-3A-4 Preservation of Biochemicals	10^4 BPS 3 3 MHz	2 16 x 10^8 4 Hrs Day	0 54 x 10^8 BPD None	1 64 x 10^8 BPD 4 Hrs	None	None None	None	None	None	None
MS-3A-5 Physical Processes In Fluids	10^4 BPS 3 3 MHz	4 32 x 10^8 4 Hrs /Day	2 16 x 10^8 BPD None	None 4 Hrs Day	2 16 x 10^8 BPD None	None None	None	None	None	None
MS-3B-1 Crystal Growth From Vapor	10^4 BPS 3 3 MHz	21 6 x 10^7 BPD 6 Hrs /Day	2 16 x 10^7 BPD None	None 6 Hrs /Day	19 4 x 10^7 BPD None	None None	None	None	None	None
MS-3B-2 Free Casting of Metals	10^4 BPS 3 3 MHz	10 8 x 10^7 BPD 3 0 Hrs /Day	2 7 x 10^7 BPD 1 Hr	None 2 Hrs	8 1 x 10^7 BPD None	None None	None	None	None	None
MS-3C-1 Metal Matrix Composites	10^2 BPS 3 3 MHz	21 6 x 10^5 BPD 6 Hrs /Day	3 2 x 10^5 BPD 2 Hrs /Day	None 4 Hrs /Day	18 4 x 10^5 None	None None	None	None	None	None
MS-3C-2 Controlled Density Materials	10^2 BPS 3 3 MHz	18 x 10^5 BPD 8 Hrs /Day	9 x 10^5 BPD 2 Hrs /Day	None 6 Hrs /Day	9 x 10^5 BPD None	None None	None	None	None	None
MS-3C-3 Preparation of Glasses	10^5 BPS 3 3 MHz	21 6 x 10^8 BPD 5 Hrs /Day	2 16 x 10^8 BPD (10^4 BPS) 2 Hrs /Day	None 3 Hrs /Day	1 94 x 10^8 BPD None	None None	None	None	None	None
MS-3D-1 Liquid Dispersion	10^2 BPS 3 3 MHz	14 4 x 10^5 BPD 4 Hrs /Day	2 16 x 10^5 BPD (15 BPS) 1 Hr /Day	None 3 Hrs /Day	12 2 x 10^5 BPD None	None None	None	None	None	None
MS-3D-2 Glass Processing	10^5 BPS 3 3 MHz	21 6 x 10^8 BPD 6 Hrs /Day	2 1 x 10^8 (10^4 BPS) 2 Hrs /Day	None 4 Hrs /Day	19 44 x 10^8 BPD None	None None	None	None	None	None
MS-3E-1 Supercooling and Homogeneous Nucleation	10^4 BPS 3 3 MHz	73 8 x 10^7 BPD 8 Hrs /Day	7 3 x 10^7 BPD 1 Hr /Day	66 42 x 10^7 BPD 7 Hrs /Day	None None	None None	None	None	None	None

Note BPD = Bits per day

Figure 2. 2-5 GSS Experiment Data Characteristics Summary

organization and operations The Phase B Modular Space Station study provides a picture of an orbiting research facility with evolving capability and purpose. It describes the growth increments and systems with which the experiment program and the ground data systems must interface

The growth of the orbiting facility is indicated in Figure 2 3-1, showing both an initial capability (ISS) and a growth version (GSS) The Modular Space Station is initially assembled by orbiting a power subsystem module, (1), and later connecting a crew operations module, (2), to form the minimum group of habitable modules Additional modules are added as required to provide more crew space, power, or facilities in which to conduct scientific and technical investigations Resupply support to the space station is provided by means of logistic modules (LOG-M1 and LOG-M2) brought up and returned by the shuttle orbiter

The data systems provided onboard the Space Station for the management of the mission and experiment data are shown in Figure 2 3-2 These systems are distributed over all of the space station modules, but are connected to a central data bus system Experiment data and crew interfaces are shown connected to the data bus through terminal units as are the elements of the DMS which allow for control and supervision The terminal units provide a pathway for outbound control signals as well as incoming data

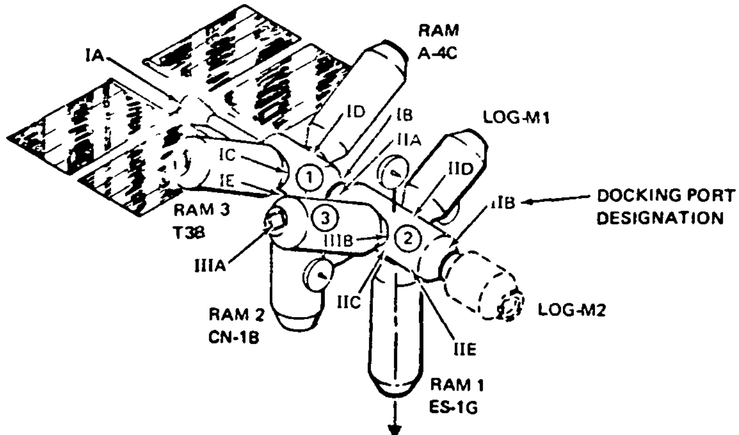
The principal functions incorporated in the onboard Data Management System include

- Data acquisition
- Data processing
- Command, control and display
- Data communication and storage

Management of data and control of data management operations are accomplished by a central unit under control of a software executive, manual control system onboard, and/or manual control through telemetry uplink

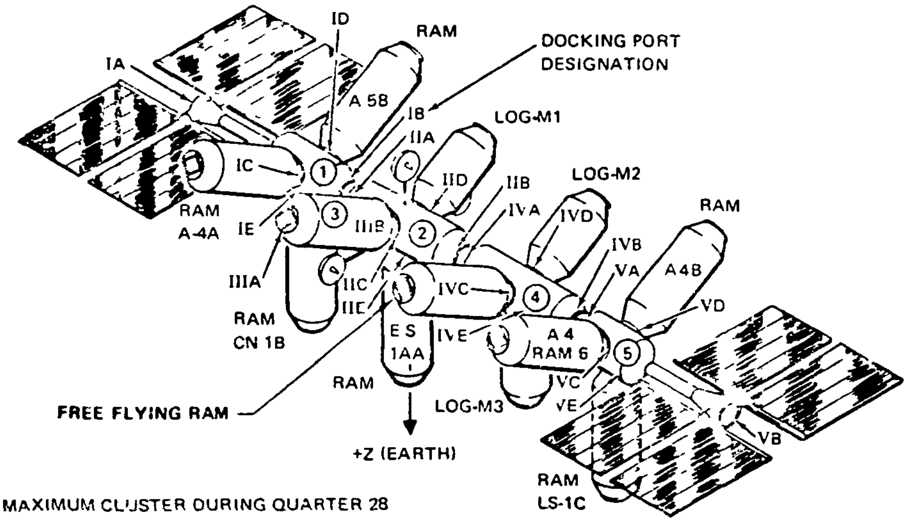
The onboard data management system processes data for the purposes of experiment control and evaluation, to reduce the overall volume of data retained and to facilitate the scheduling of operations and trafficking of data Storage is provided to hold experiment data and mission data until decisions can be made relative to its disposition As a result of computer evaluation or manual review, the data is routed to the communication system, permanent storage or, as a result of evaluation, eliminated due to quality or content

The storage system will be organized so that experiment data is effectively sorted and merged onboard the space vehicle using code sensitive data bus terminals The data, coded at the sensor data bus terminal with a destination code, is accepted only by the designated buffer and loaded on tape using a dedicated digital tape recorder The dedication is programmable and can be re-dedicated during periods when a particular experiment is not running The basis of dedication will generally be according to discipline, however, for earth resources, there are additional subdivisions



MAXIMUM CLUSTER DURING QUARTER 15

LAUNCH SEQUENCE/MODULE	1	2	3	
PRIMARY FUNCTION	POWER/ SUBSYS	CREW/ OPNS	GPL	LOG M



MAXIMUM CLUSTER DURING QUARTER 28

LAUNCH SEQUENCE MODULE	1	2	3	4	5
PRIMARY FUNCTION	POWER/ SUBSYS	CREW/ OPS	GPL	CREW/ OPS	POWER SUBSYS
			ISS		GSS

Figure 2. 3-1. Space Station Configurations

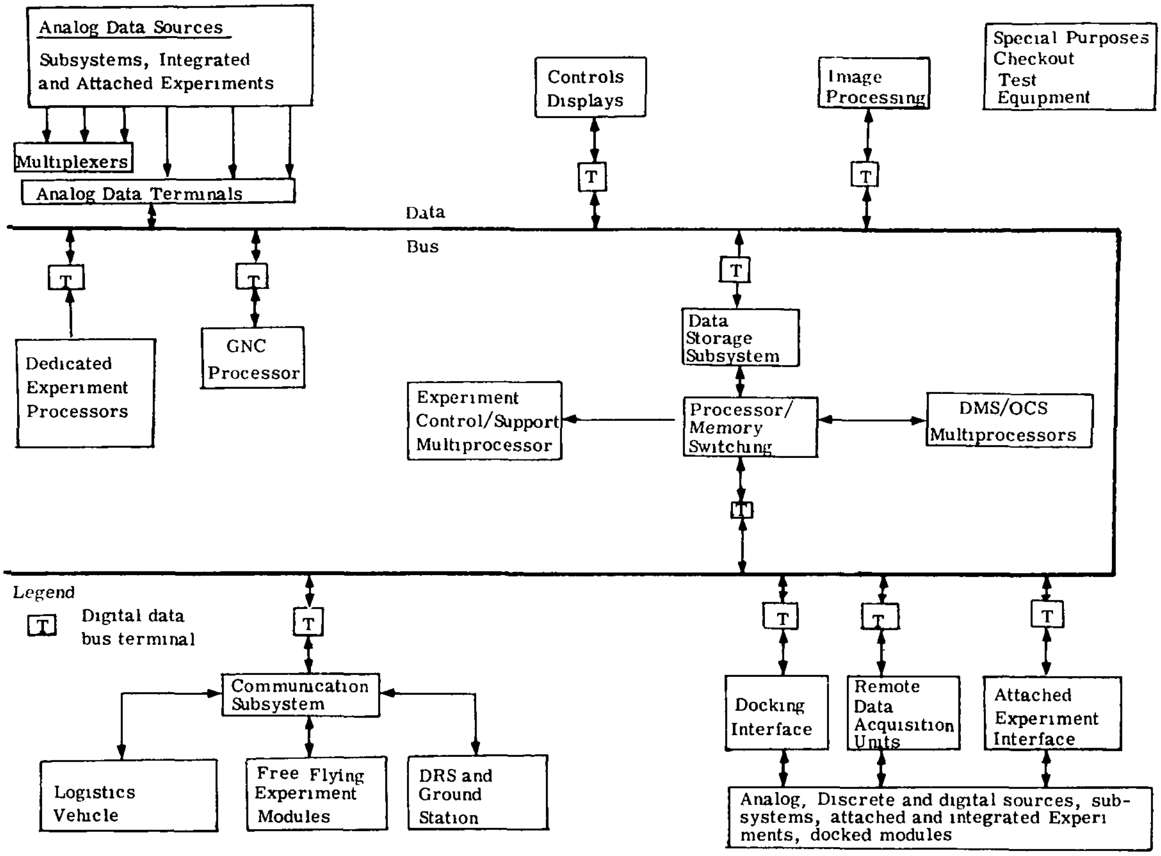


Figure 2 3-2 Onboard Information Management System

The data system implementation is modular as is the space station itself The functions provided by each module are shown in Figure 2 3-3, Data Management System Functional Allocation As mentioned earlier, the capability of supporting either crew habitation or program control requires both the power module and the crew module No 1. Crew module No 1 contains most of the control systems and software necessary to conduct both the mission and the experiment program Crew module No 2 provides backup for module No 1 plus extensive capability for conducting additional experiments Complete communication capability is provided by crew module No 1, again backed up by the same capability on crew module No 2 Subsequent modules provide only those portions of the system required by the experiments contained in the particular module.

By using an experiment program and a schedule similar to that used in the Phase B Space Station study, the characteristics and capacity of the onboard system are directly applicable as a data input model for the data flow study for which ground data handling systems will be specified The design features for the modular space station are shown in Figure 2 3-4 The data system capability contained in the first three modules represents the total data handling requirements for the initial space station Modules 4 and 5 represent the addition that the Growth Space Station will require In addition to experiment data channels, a number of audio and video channels are required for operational purposes

Power Module	Crew Module #1	Crew Module #2	GPL	Experiment #1	Experiment #2
COMPUTER FUNCTIONS					
• Attitude Control • TM Formatting • Checkout	• Executive • Guidance, Navigation • Attitude Control • Rendezvous and Docking • Flight Operations - Data Control - Subsystem Control • Display • Orbital Checkout Subsystem	• Same as Crew Module #1 for Backup PLUS • Experiments - Process - Control	• Operational and Checkout Processing for Factory and Prelaunch Activities	• Operational and Checkout Processing for Factory and Prelaunch Activities	• Operational and Checkout Processing for Factory and Prelaunch Activities
NOTE The computer function listed under the headings 'Crew Module #2" and 'GPL" could be performed in the respective experiment modules Final location will be dependent on equipment configurations					
COMMUNICATIONS					
• Telemetry/ Command - MSFN - Shuttle • Tracking - MSFN - Shuttle	• Telemetry/Command - MSFN - Shuttle - Intelsat • Tracking - MSFN - Shuttle • Video - MSFN - Intelsat • Voice - MSFN - Shuttle - Intelsat IV	• Same as Crew Module #1			
DATA ACQUISITION AND DISTRIBUTION					
• Status - Operational Subsystem • Operational Data • Commands/ Controls	• Status - Operational Subsystem • Operational Data • Command • Voice • Video	• Same as Crew Module #1	• Status - Operational Subsystems and Sensors • Experiment Data - Analog - Digital - Video	• Status - Operational Subsystems and Sensors	• Status - Operational Subsystems and Sensors
Intercom					
DISPLAYS AND CONTROLS					
• Operational Control (Remote Command) • Portable Display	• Command/Control Console - Integrated Display - Multipurpose Display - Video	• Same as Crew Module #1	• Portable Display	• Portable Display	• Portable Display
DATA STORAGE					
• No Storage	• Program File Tapes	• Digital Store-Bulk Data • Video Store-Bulk Data	• Photographic Film • Experiment Samples • Book, Log, Records		

Figure 2. 3-3. Data Management System Functional Allocation

	Power Module 1 1	Crew Module 1 2	GPL 3	ISS TOTALS	Crew Module 2 4	Power Module 2 5	GSS Totals
Subsystem Data Sources	2315	1970	1238	5523	1602	2131	9256
Worst Case Subsystem Data Rate	52 KBPS	42 KBPS	23 KBPS	117 KBPS	35 KBPS	48 KBPS	200 KBPS
Experiment Data Rates				2 4 MBPS*			8 6 MBPS**
Total Data Rate				2 5 MBPS*			8 8 MBPS**
Analog Requirements	Audio 48 Telephone Channels 1 Public Address 1 Emergency Call Tone 1 Emergency Alert Tone 3 Entertainment Channels			Video 8 TV Channels, 4 75 MHz Baseband 1 Test Channel, 4 75 MHz Baseband 1 TV Carrier Reference, 4 MHz Sine Wave			

* Excludes 50 MBPS from ES-16 Land Use Mapping
** Excludes 51 8 MBPS from ES-1AA and 9 5 MBPS from A-3CC (A Free Flyer)

Figure 2. 3-4 Space Station DMS Design Features

2.4 USER REQUIREMENTS

Performance functions of the Ground Data Handling System will be designed to the set of capabilities and services necessary to fulfill the user needs System capability will be determined by the four principal interfaces each configured in response to user requirements

- Experiment hardware – the sensors and systems selected on the basis of user information needs
- Experiment and mission operations – the schedule, based again on user needs for coverage and observation repeats
- Data dissemination - the form and distribution of system outputs.
- User products – the degree of thoroughness and accuracy establishing the delivered quality, quantity, and determining the extent of preprocessing expected from the data handling system

Experiment hardware, i e , the particular sensors chosen to provide the information required, will determine

- Data types
- Data rates
- Data quantities
- Data delays (due to recording medium)

Since the orbital parameters determining coverage are fixed, the flow of data to a particular user is a function of target availability, crew time available, and the user's need for repetitive coverage

Because user needs, in the broadest sense, are the prime consideration in experiment, sensor and system function selection, a considerable portion of the study was spent collecting and analyzing inputs from the user communities

The following sections identify and define the results of a survey and analysis of requirements uniquely related to the use of data These requirements encompass the functions of

- Data delivery
- Data and experiment interaction
- Preprocessing
- Temporary storage
- Archival

2.4.1 USER CONTACTS

Members of the Space Station experiment subpanels were designated as a beginning point for contact with users Members of the subpanels, for the most part, recommended additional contacts in both the science and application areas In addition to bonifide data users, a number of contacts in industry were made to identify state-of-the-art in several key technical areas such as archiving systems and component technologies

A list of persons interviewed is shown in Appendix A These individuals represent users in every scientific and technical area included in the baseline experiment program The table shows the spread of interests in terms of disciplines as well as the organization or institutional affiliations

In all, there were over one hundred individuals contacted Some had previous experience with NASA and the space program and some anticipated future participation, either directly as experimenters or indirectly as users of data

The contacts made not only were an invaluable source of current thinking in terms of data and service needs but also provided an infusion of fresh ideas on future trends in the disciplines

A number of general observations can be made as a result of User discussions

- Mechanisms exist for User servicing
- The Users are currently geared to non-digital data
- The Users do not comprehend the potential avalanche of data

- Basic science Users have access to adequate analytical facilities

- Applications Users generally do not have sufficient analytical capacity

On the basis of User contacts only, the following conclusions can be made as a candidate approach to configuring a Ground Data Handling capability using a "bottom up" analysis

- Many Users will require analytical aid

- Users need ready access to data and data bases

- Existing User servicing organizations should continue to be used where possible

- Interaction will enhance operational efficiency

2.4.2 WHO ARE THE USERS

Traditionally, the user has operated within NASA as a development consultant as well as a data consumer in a specific science area As the principal investigator, the user enjoyed exclusive use of the outputs of the sensors for which he was responsible Although the principal investigator role may continue in the area of research and development, the trend is moving toward a more applications oriented program where NASA provides sensors and scientists and the resulting data is available for the widest possible application The users who receive data routinely from NASA will far outnumber the principal investigators

The organizational or operational picture of the typical user revealed through the study contacts can be characterized as belonging to one of the three types shown in Figure 2 4-1

The closeness of individual or organizational affiliation with NASA will be largely determined by the kind of use that will be made of the data The type A user who interfaces directly with NASA has a position and a responsibility much like the principal investigator His closeness belies his greater obligation to NASA with respect to data use His need is for data to research and develop sensing technology and processing techniques The R&D oriented user provides the updating of sensors and techniques through the feed-back path shown as an aid to mission planning and experiment/sensor selection It will be through the development efforts of this type of user that full data utility can be realized

The basic science researcher (type B) is much like R&D (type A) user except that his principal responsibility is to another organization – like a university – that provides the interface to NASA Because the organization usually supports more than one researcher the interface to NASA (the data source) is a composite of the requirements of all the users serviced by the organization The requests and comments fed back may well be translated into requirements that become the objectives of the R&D groups

Even though early mission emphasis is on technical rather than science or applications goals, the information collected will certainly be of value to the scientists such as physicists and astronomers and to the scientists who are striving to better husband our natural resources These users who may be less directly connected with the data collection will never-the-less

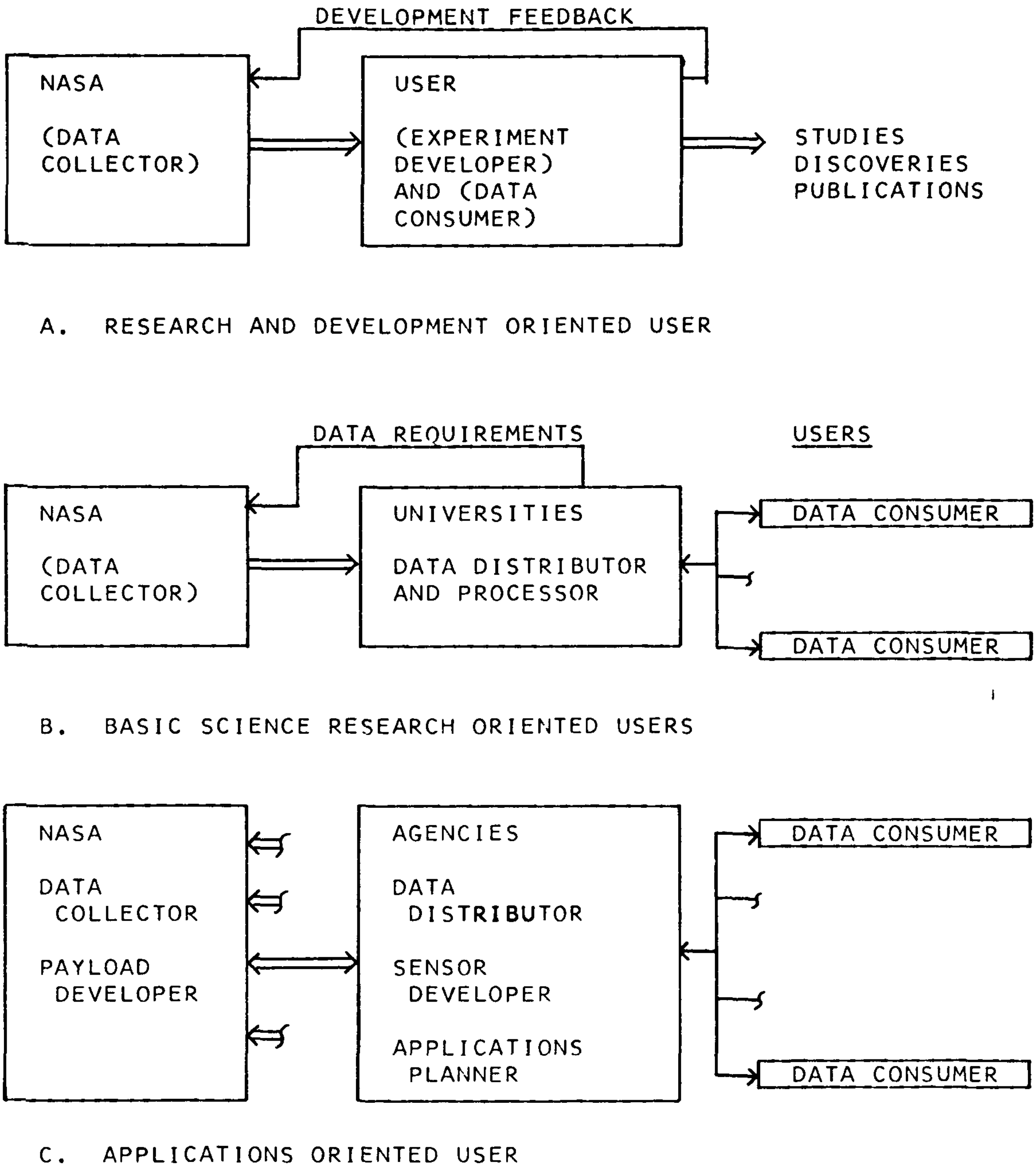


Figure 2. 4-1. Typical Users

have access to data relating to their problems Typically, these users may interface with a government agency such as the Department of Agriculture or the Department of Interior for their data and be able to communicate additional requirements to NASA for consideration This group of users is shown as type C users

There are many additional ranks of users who interface at any one of the levels shown who will use information, the farmer who uses weather prediction for his planting and harvesting, the mass media who use pictures and information to keep the public aware of space efforts, and the publishers who can use information for compiling references and articles

The requirements for data collection and distribution are woven around these three classes of users that represent the hundreds of individuals who are expected to make use of space derived data

2.4.3 TYPICAL USER PROFILE

As a result of the contacts made with users, using agencies, and application planners, it became increasingly evident that similarities among users could be used to group users into a few key classes These classes, in general, are characterized by the way in which data is being used These are

- Basic science research
- Technical and operation research and development
- Application to social, economic and environmental problems

Each of the space activities that results in data has some aspect of all the classes, however, by keeping the division relatively sharp, a crisp insight into support system capability can be gained

2.4.3.1 Basic Science User

Users of data, exemplified by astronomy, physics, medicine, and some of the bioscience experiments, will use data in an exploratory manner, that is, a detailed search will be made through the data for the anomaly and the unexpected In addition, the more subtle features will be studies by long term analysis using analytical tools that evolve with analytical findings

Scientists who make use of the space research facilities are generally already grouped about a common research facility and can work through the existing organization to obtain and analyze space data An example of such an organization is the Association of Universities for Research in Astronomy (AURA), better known as the Kitt Peak Observatory The consortium of astronomers from a number of universities has acquired the tools for observing and analyzing solar data These same analytcial tools provide sufficient capability to analyze the data collected through space missions

In terms of real time data flow and user interaction, the basic science researcher covers the total spectrum of requirements from real time participation in experiment operation – required in physics, through occasional monitoring and update of ongoing acitvities – required by

stellar astronomy to little or no interaction in real time as required by the high energy physics experiment Interaction amounts to assistance from the ground for determination of valid onboard operations It may be required because of a lack of scientific expertise onboard the space vehicle or because of insufficient system capability to make the determinations onboard In either case, consultation with a principal user can assure validity as well as reduce the time he requires the experiment to be operated

2.4.3.2 Technical/Operations User

Users of data for technical and operational R&D do not, as a rule, require either timely data response, raw data, or interaction Because the results of technological experiments describe trends in hardware characteristics and physical processes, the need is for information (meaning) rather than for detailed parameter history Experiments requiring duplicate or control activity on the ground do require timely data Data for these users can be in the form of summary data and physical samples Photographs of significant events and operations will accompany system information

Experimenters and principal data users of the technical experiments typically belong to a government agency The user community is made up of the lead agency (usually NASA) who will provide data to vendors and designers for technical evaluation and system development Experimenters typical of this class include

- Teleoperator development
- Materials sciences and fabrication
- Contamination measurement and control

2.4.3.3 Application User

Application experiment users form the largest of the three classes It is composed of developers, who are determining improved methods of application, and a hierarchy of government organizations on Federal, State, and Local levels

Because of the limitations of currently analytical techniques, many of the users will want only photographic data – even the non-photographic data will be converted to film – for their interpretive analysis The usefulness of applications data, thus the size of the user community, will depend upon both development of user tools and data quality (it is assumed that all coverage and resolution requirements can be met initially)

Applications occur principally in the area of earth resources management and planning but there are also aspects of application to be derived from both technological and science experiments. Examples are the materials science experiments can result in processes useful for commercial exploitation, in medical experiments where techniques and understanding may be discovered that are beneficial to all mankind, and in physics and astronomy where a clear and current knowledge of solar and atmospheric dynamics can lead to better, more effective communication predictions These data, too, will be made available to the application oriented users

Because of the current emphasis, the widespread applicability of Earth Observations data and the need for extensive correlation of ground truth measurements, it stands out as the major contributor of support requirements The limited capability possessed by the typical users in earth resources creates a broader range of support functions required than in all other experiment areas combined

2.4.4 USER DATA REQUIREMENTS

Each of the Users contacted and all of the experiment studies have estimated the data required from the experiment in response to a variety of operational environments The numbers once taken out of context have little meaning apart from the stated operating schedules and separated from the application modes This section lists desires of the Users in order to establish a baseline of data requirements that the ground system must meet

2 4 4.1 User Needs

Each of the Users contacted was asked how much data would be required from the experiment sensors to provide the type of operational visibility necessary to assure validity The requirements took the form of various time delays based on the type of experiment and the criticality of measurement The delays ranged from virtually none (real time) up to a week The shortest delay requirement involved direct participation of the ground based experimenter in the positioning of sensors, selection or evaluation of targets and similar activities The following charts and tables summarize user needs in terms of data quantity and return mode

Representatives of Users in each of the seven disciplines identified the response requirements indicated in Figure 2 4-2 Although the numbers have a considerable spread, the requirements can be expressed in three distinct categories

- Real time (transmitted in minutes)
- Delayed (transmitted in days)
- Recorded (returned monthly via Shuttle)

Using the schedules developed in Section 2 2 1 and the experiment characteristics defined in Section 2 2 2, data quantities for each of these categories can be identified

The daily schedule of experiment operation is shown again in Figure 2 4 3 with data characteristics for each of the experiments superimposed By adding the data rates vertically, data profiles can be developed for RF data (a composite of real time and delayed data) and the quantity of data stored onboard the space vehicle to await the shuttle return

RF Data

The downlink and Ground Data Handling facility input capacity size depends upon the requirement for timely data The maximum capacity will be either the bandwidth required to accommodate the greater of the average (buffered) rate of delayed data or the peak rate of real time data Figure 2 4-4 shows the peak real time data rate to be the driver for both ISS and GSS In the case of ISS, the composited delayed data requirements fill in between the

Experiment	Data Form	Real Time RF Data Required*	Delayed Data RF Required*	Recorded For Shuttle Return*
Life Support	Video Digital	On Demand None	------ All Within 90 Min	------ None
Technology	Video Digital	10% 10% to None	 0 - 50%	90% (Film) 50 - 100%
Communications/Navigation	Digital	20%	None	80% (Film)
Earth Observations	Digital	1%	10 - 15%	85% (Film)
Physics	Digital	0 - 10%	None	90 - 100% (Film)
Materials Science Manufacturing	Video Digital	0 - 30% 10 - 50%	0 - 100% None to 100%	None (Film) None
Astronomy	Video Digital	All All	None None	None (Film) None

*All numbers in percent of total.

Figure 2. 4-2. User Requirements for Electronic Data Response

real time peaks to result in a 600K bit per second digital data rate for ISS In the case of GSS, the utilization of downlink capacity established by the peak real time data rate is not good The peak real time rate required is 6M bits per second while the average rate of real time and delayed data is under 3M bits per second It is believed that further discussions with the experimenters who require such high rates for real time data will relax the timeliness requirement to allow more averaging of the peak rates

The buffer sizes holding experiment data for transmission are shown in Figure 2 4-5 The total buffer sizes 4 1 X 10^9 bits (ISS) and 2 1 X 10^{10} (GSS) are made up of

- Real time buffer for storage of single images
- Post collection buffer for storage of delayed data
- Communication coverage gap buffer to hold data until communications can be re-established

In addition to the realtime digital data, some realtime video is needed Figure 2 4-6 shows the time-bandwidth profile of the composite requirement for both ISS and GSS The same statements can be as to poor bandwidth utilization as was made about peak digital requirements The large difference between peak and average rates may be helped somewhat by further negotiations with the experimenter However, the recognized requirements are 10 MHz for ISS and 11 MHz during GSS

The video will also have to be buffered during the communications gaps (approximately 5 minutes)

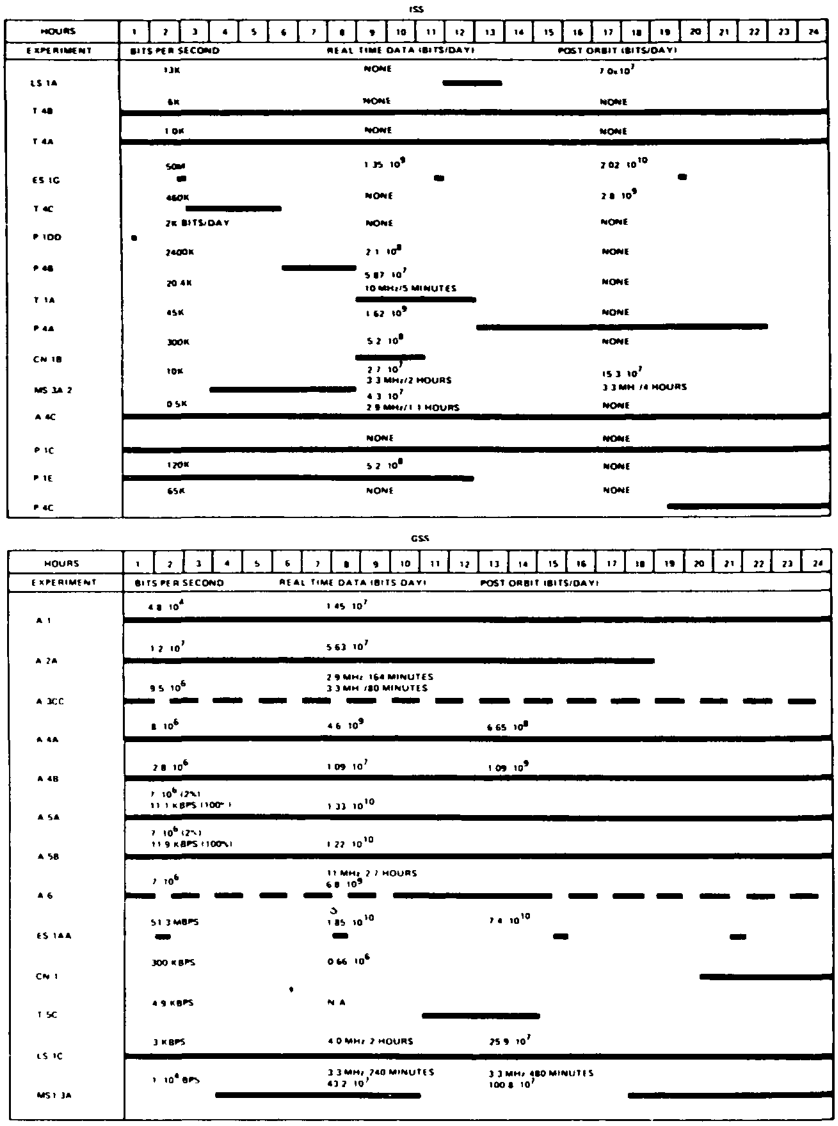
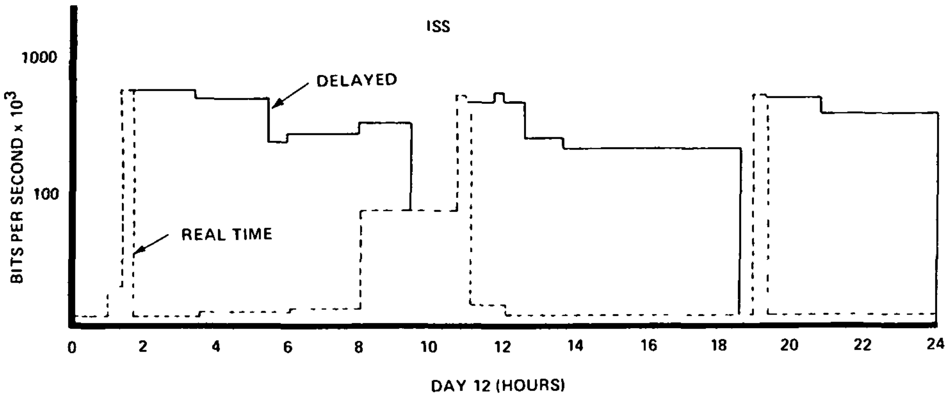


Figure 2. 4-3. Daily Schedule with Data Rates

Recorded Data

The principal mode of data return will be in the form of digital data recorded on high density magnetic tape The profiles shown in Figure 2 4-7 show the rates at which digital data is generated for those experiments operated during the daily schedule shown previously The extremely high rates indicated (74M bits per second) for ISS can possibly be reduced by re-scheduling since the rate is caused by simultaneously operating sensors The monthly accumulation, however, will remain the same The highest rate indicated for GSS (50.1 M bits per second) come from one experiment and can only be reduced by reducing the number of channels operating



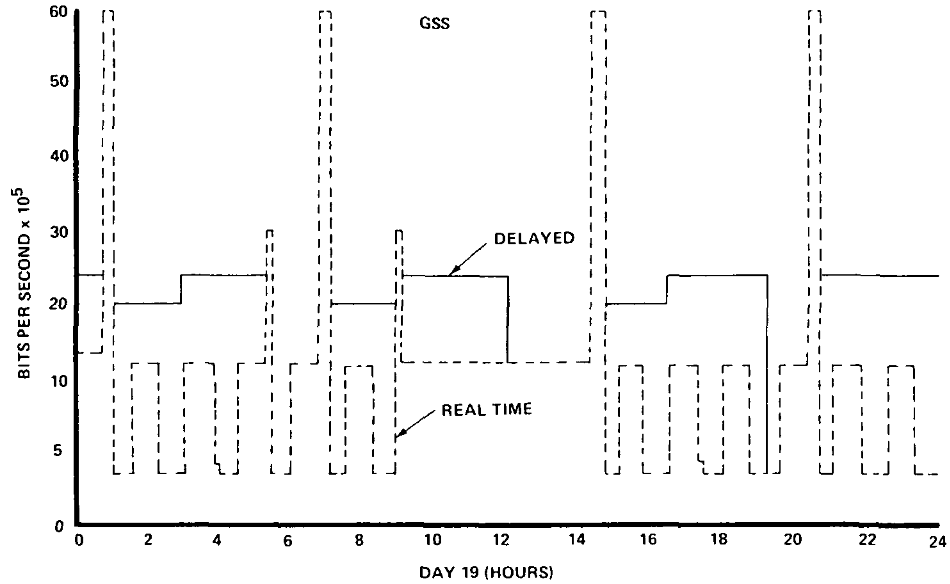


Figure 2. 4-4. Digital Data RF Requirements

The total of digital data generated each day (26 days per month) is shown in the summary chart in Figure 2 4-8, of the total data generated by ISS and GSS, 9% and 16% respectively are returned via RF The balance of the data is recorded and returned with film and samples also generated by the experiments The logistics requirements caused by recorded data are summarized in Figure 2 4-9 Logistics impacts are minimized by using the highest density recording on magnetic tape that appears feasible during this time frame Characteristics for the recording media used are listed in Table 2 4-1

	ISS	GSS
TOTAL DIGITAL DATA BUFFER (BITS)	$4\ 1 \times 10^{9}$	$2\ 1 \times 10^{10}$
• REAL TIME	$3\ 1 \times 10^{8}$	$4\ 6 \times 10^{8}$
• POST ORBIT	$3\ 5 \times 10^{9}$	$1\ 9 \times 10^{10}$
• COMMUNICATION GAP	$2\ 6 \times 10^{8}$	$1\ 1 \times 10^{9}$
VIDEO BUFFER (COMMUNICATION GAP)	10 MHZ (5 MINUTES)	11 MHZ (5 MINUTES)

Figure 2. 4-5. Communications Buffer Requirements

2 4 5 USER REQUIREMENTS SUMMARY

The results of this analysis establishes by traceable steps the quantity of data required by the User, the data response needed, and some insight as to the nature of the data and the capability of the User to assimilate the expected quantities

The rates, although appearing high in the profiles shown are not unmanageable because of the multichannel nature of the sensors The highest single channel rates will not exceed 12M bits per second

The large quantities of data delivered to the Ground handling facility each month by Shuttle return have been reduced in bulk by using a high density recording medium and have been sorted onboard into disciplines and/or subdisciplines

The data loading of the onboard DMS as well as the communication links have been checked for reasonableness and appear to be within the capability of existing hardware capability

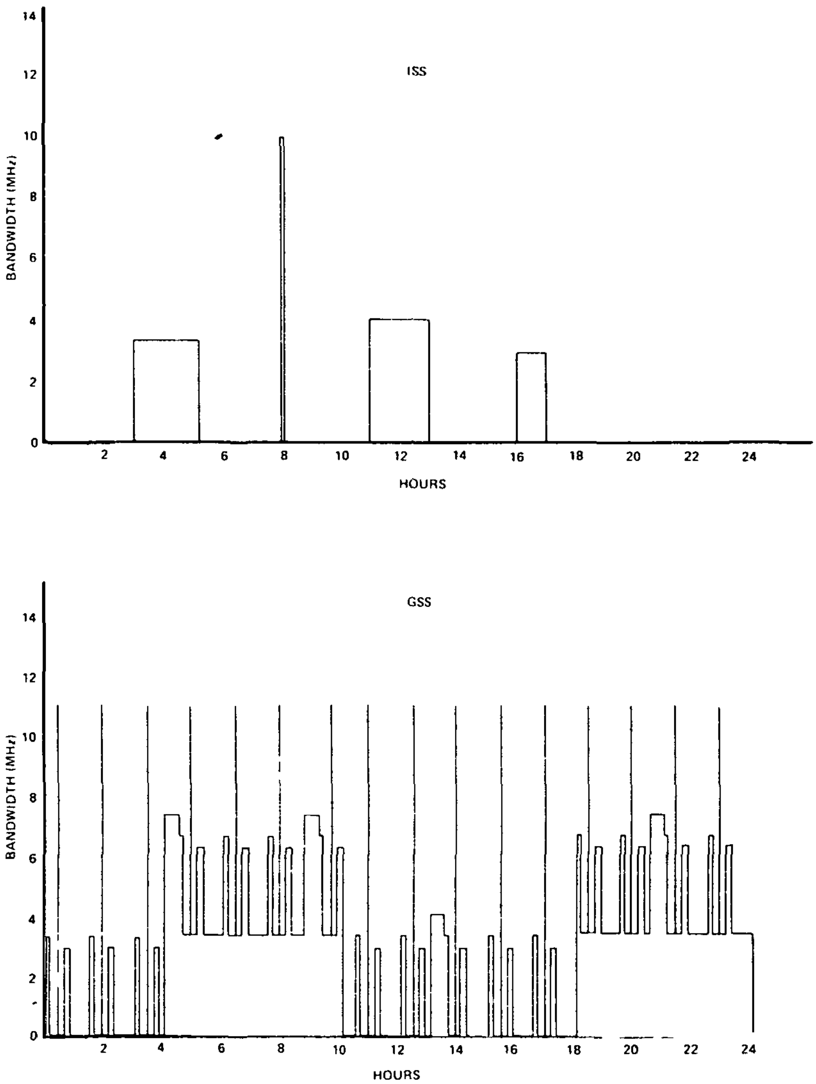


Figure 2. 4-6 Real-Time Video Requirements

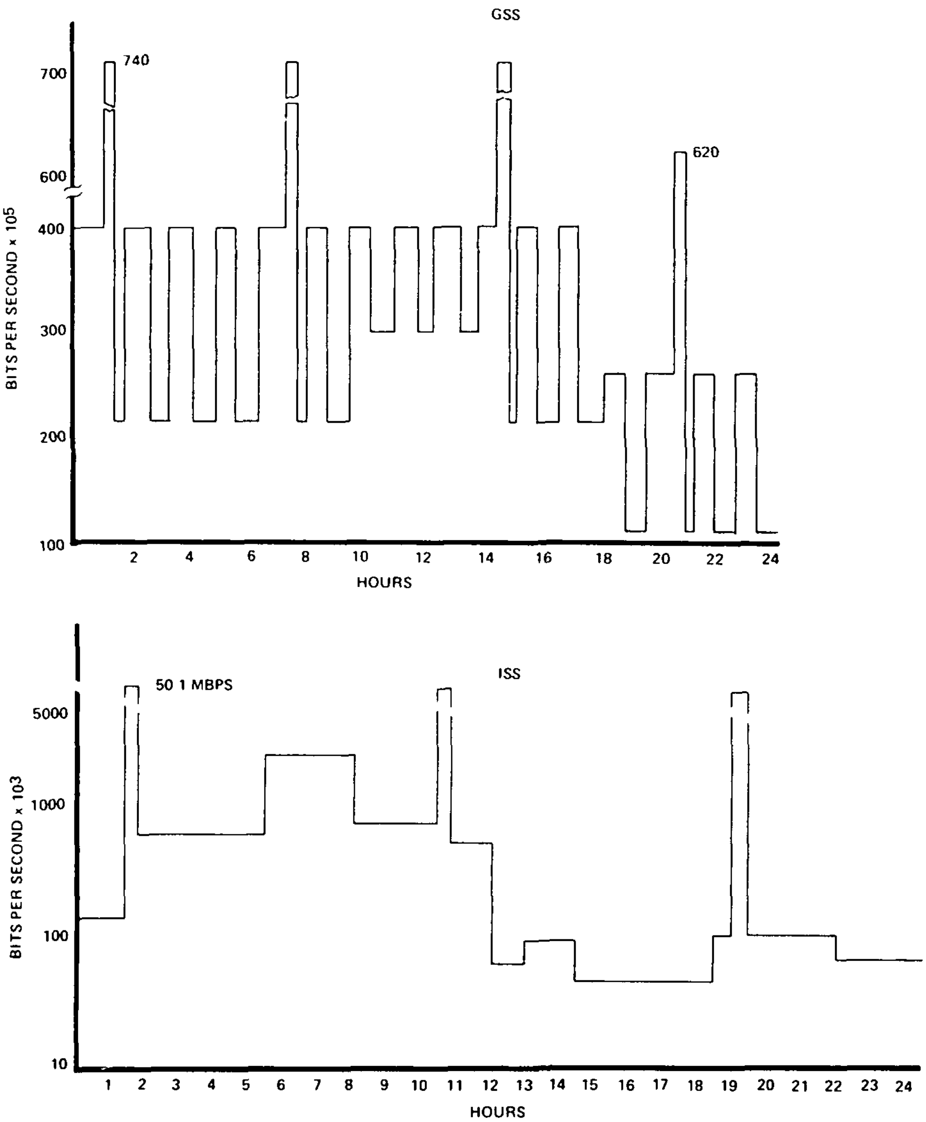


Figure 2 4-7. Digital Data Rate Profiles

Table 2. 4-1. Magnetic Tape Recording Characteristics

Recording Density & Weights (Digital)

Digital Recording	Analog Record
Width – 2 54 cm (1 inch)	Width – 5 08 cm (2 inch)
Length – 1402 m (4600 ft)	Length – 1524 m (5000 ft)
Weight – 2 72 Kilograms (6 lbs) (including reel and package)	Weight – 4 5 Kilograms (10 lbs) (including reel and package)
Record Density – 48 Channels, 3945 bits/channel cm, (10^4 bits per channel inch)	Reference Tape Speed – 30 48 cm/sec (12 inches/second) for 6 MHz response
Record Capacity – 2 65 X 10^{10} bits per reel	
Tape Speed – 50 8 cm/sec (20 inches/Sec)	

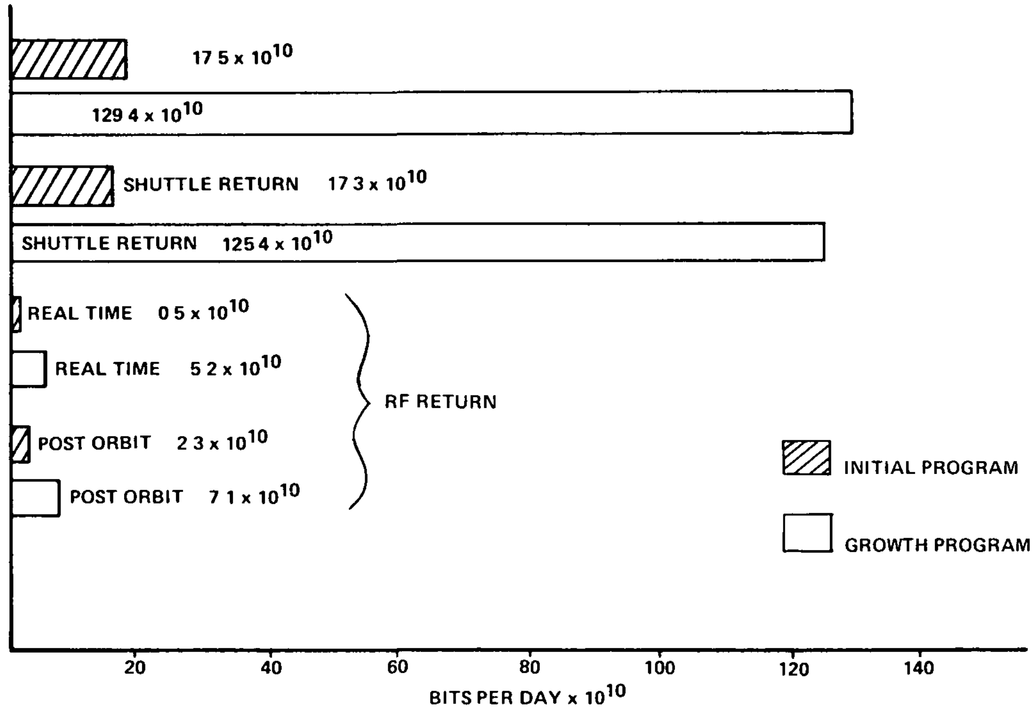


Figure 2 4-8 Daily Data Quantity

DATA TYPE	ISS	GSS
DIGITAL	119 REELS OF TAPE	609 REELS OF TAPE
VIDEO	52 REELS OF TAPE	150 REELS OF TAPE
FILM	724 REELS 16 MM 141 CASSETTES 35 MM 261 CASSETTES 70 MM 132 MAGAZINES 240 MM	572 GLASS PLATES 9 CASSETTES 35 MM 141 CASSETTES 70 MM 24 MAGAZINES 240 MM 1 MAGAZINE 150 MM
SAMPLE DATA	MS MATERIALS EMULSIONS SPECIMENS NOTES, LOGS VOICE TAPES, ETC	

Figure 2. 4-9. Shuttle Return Loading

DATA DISSEMINATION 3

3.1 INTRODUCTION

3.1.1 SCOPE

The objective of this task was to define and analyze in terms of cost and time response those concepts which could provide efficient dissemination of all data generated in the Space Station program to principal users on earth The concepts discussed herein will satisfy the data dissemination requirements posed by this study

3.1 2 METHOD

Contact with various user organizations and personnel was made to determine their "needs" versus "desires" with emphasis placed on real "need " In addition, the technology of today and reasonable extrapolations for the 1980-1990 time frame were reviewed to establish a hardware baseline A review of recent documents generated from NASA and industry study activities (e g , Phase B Space Station report) was made in an effort to incorporate those recommendations where feasible

The results from the user consultations, technology reviews, and literature search, were then used as a baseline to derive three separate but associated concepts for the dissemination of data Each of the three basic concepts (with options) was then subjected to ROM cost and response time estimates Based on this cost and response time data, several conclusions and recommendations regarding data dissemination were made

3.2 CONCEPTS FOR DATA DISSEMINATION

The concepts discussed in the following paragraphs address data in all its forms The three basic premises upon which the concepts are formulated can briefly be stated as follows

A Return of all data from the Space Station to earth via the Space Shuttle

B Direct RF transmission of all digital and analog data from the Space Station to a Central Receiving Facility (Non-transmissable data to be returned via Shuttle)

C Direct RF transmission of all digital and analog data from the Space Station to individual users via local RF receiver stations

These basic concepts with various secondary dissemination options are shown in Figure 3 2-1 and detailed in the following paragraphs

3.2.1 SHUTTLE RETURN

The first concept to be considered involves the return of all data via the Space Shuttle All returned items are enclosed within a single container designated "Shuttle Resupply Module " Upon shuttle landing, the resupply module is moved to a handling facility where the data can be unloaded, catalogued, repacked, and shipped to a specific preprocessing facility Once the various data forms are shipped to their respective preprocessing centers, the handling facility is no longer required until the next shuttle return

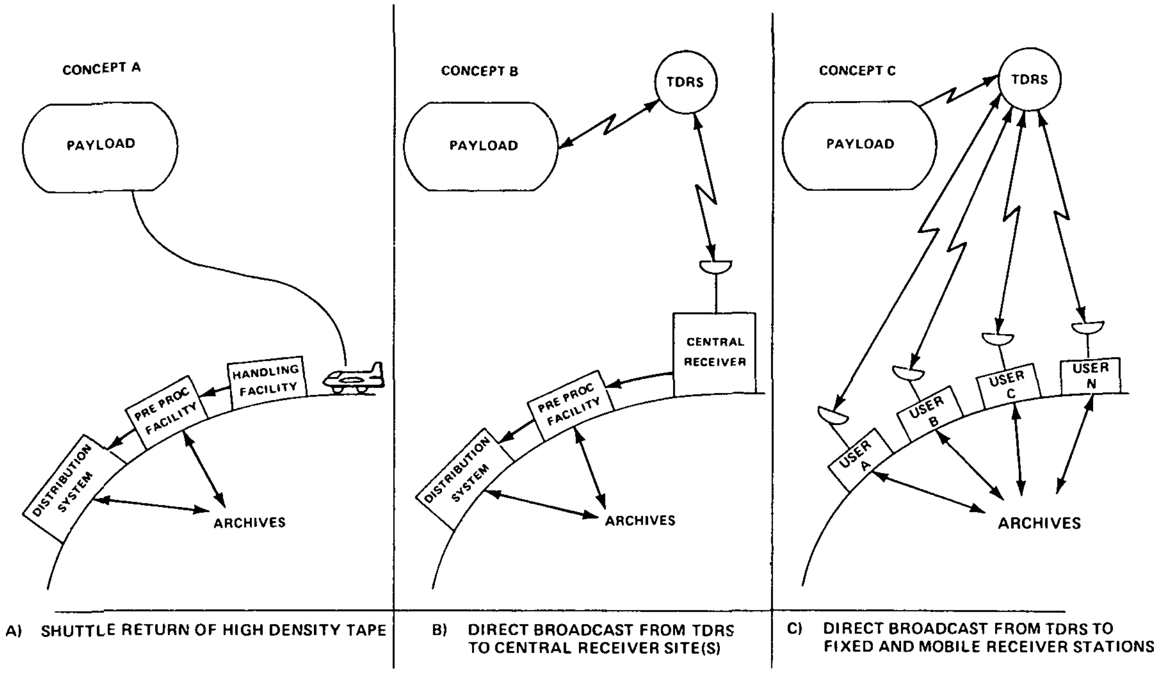


Figure 3. 2-1 Data Dissemination Concepts

Upon arrival at a preprocessing center, the raw data must be sorted by experimental discipline and merged with operational data as required Subsequent to this operation any of several different processing schedules could be initiated Figures 3 2-2 through 3.2-8 detail a complete preprocessing flow for all data in all its forms, however, since approximately 80 percent of all data is characterized as digital or analog, the following paragraphs are addressed primarily to the preprocessing and subsequent dissemination of that specific type of data It is reasonable to assume that data in other forms can be processed per the data flow charts referenced above

3.2.1.1 Sort and Merge

Once data is received at a Central Processing Center, the next major activity is "Sort and Merge " The sorting of data collected sequentially in chronological order can be accomplished in one of two ways (1) the processing center, or (2) aboard the spacecraft

The first option involves the use of a ground data bus system identical to that which is aboard the Space Station with one exception The onboard data bus collects data through numerous data bus terminals (DBT) which place the information on the bus in a random but sequential manner This sequential data train is recorded on magnetic tapes and returned via the Shuttle The exception is that in the ground system the magnetic data tapes are replayed onto the data bus, and the data bus terminals (through special coding) extract the information Each data terminal is programmed to accept only that data associated with a specific discipline The output of each terminal is a buffer storage medium of sufficient capacity to contain one 24-hour period of data for any given discipline Once

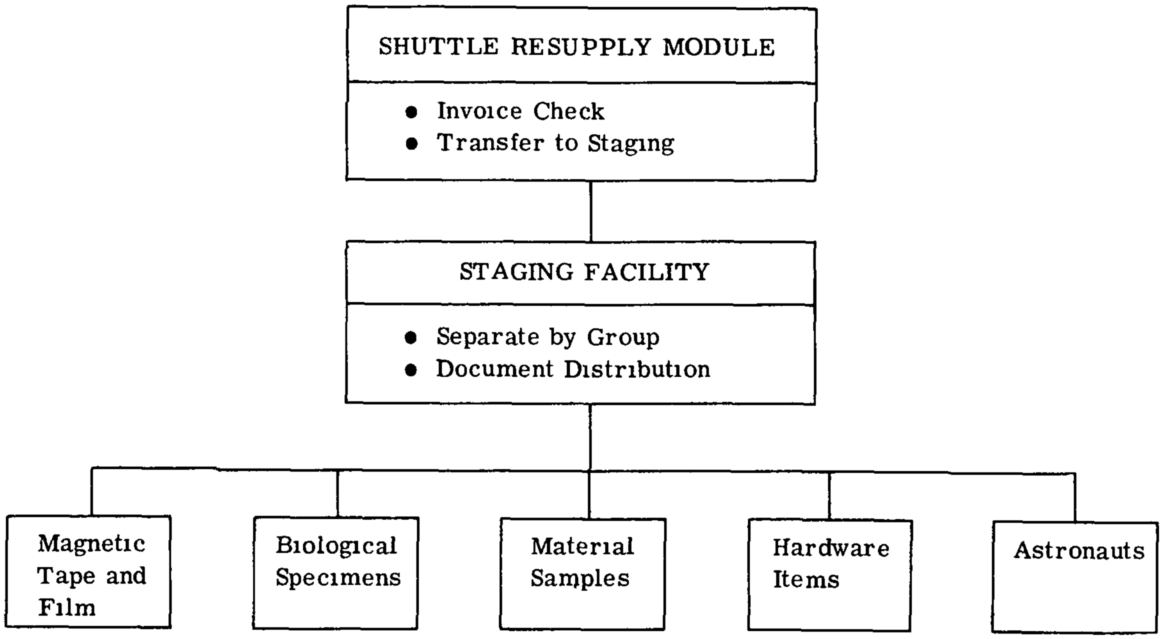


Figure 3. 2-2. Overall Processing Flow

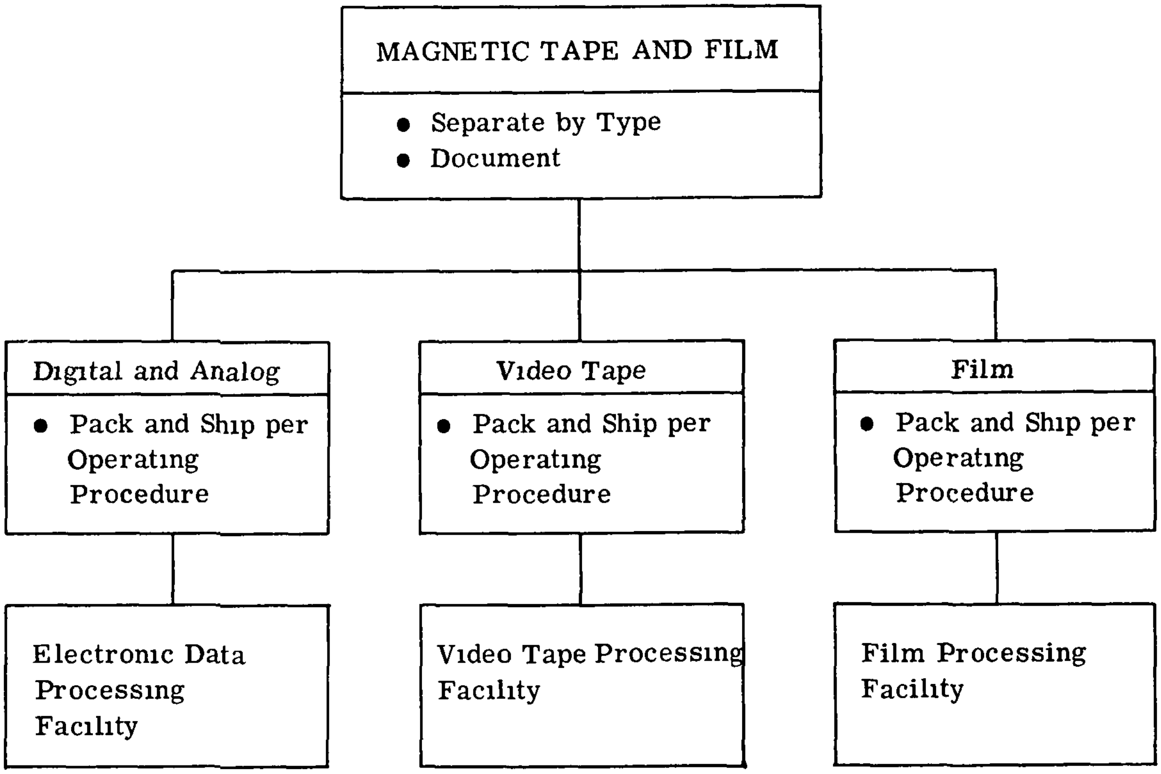


Figure 3. 2-3 Tape and Film Processing Flow

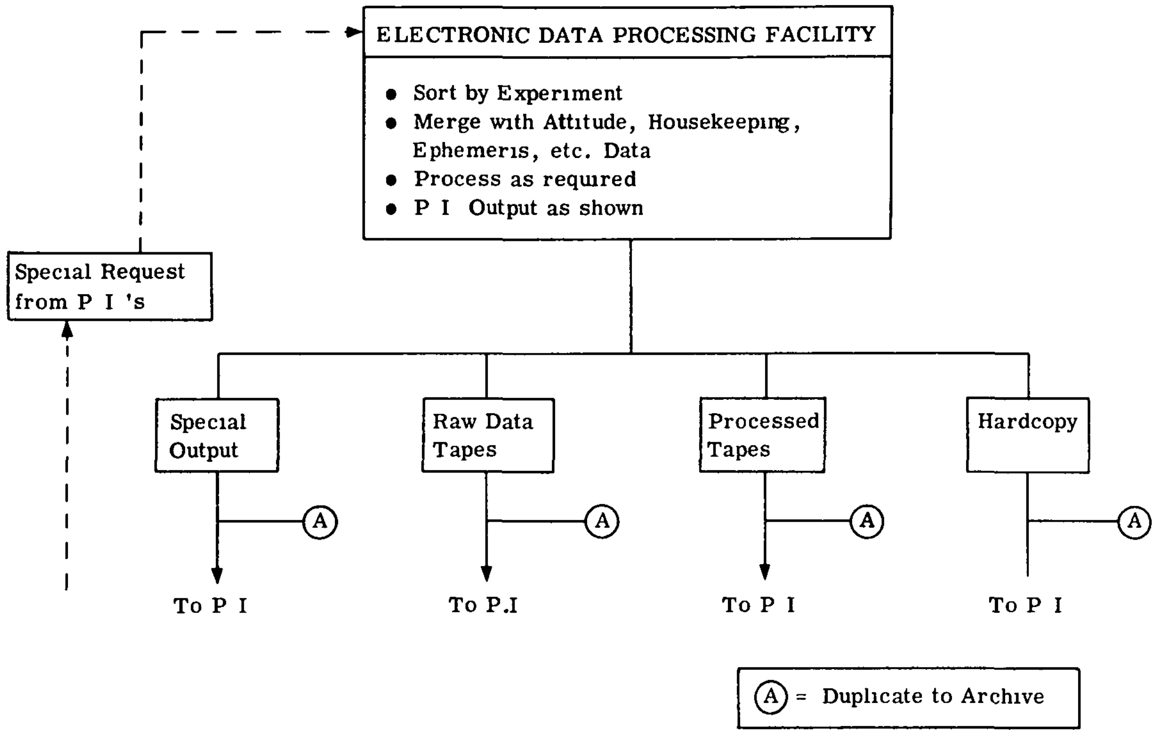


Figure 3. 2-4. Electronic Data Processing Flow

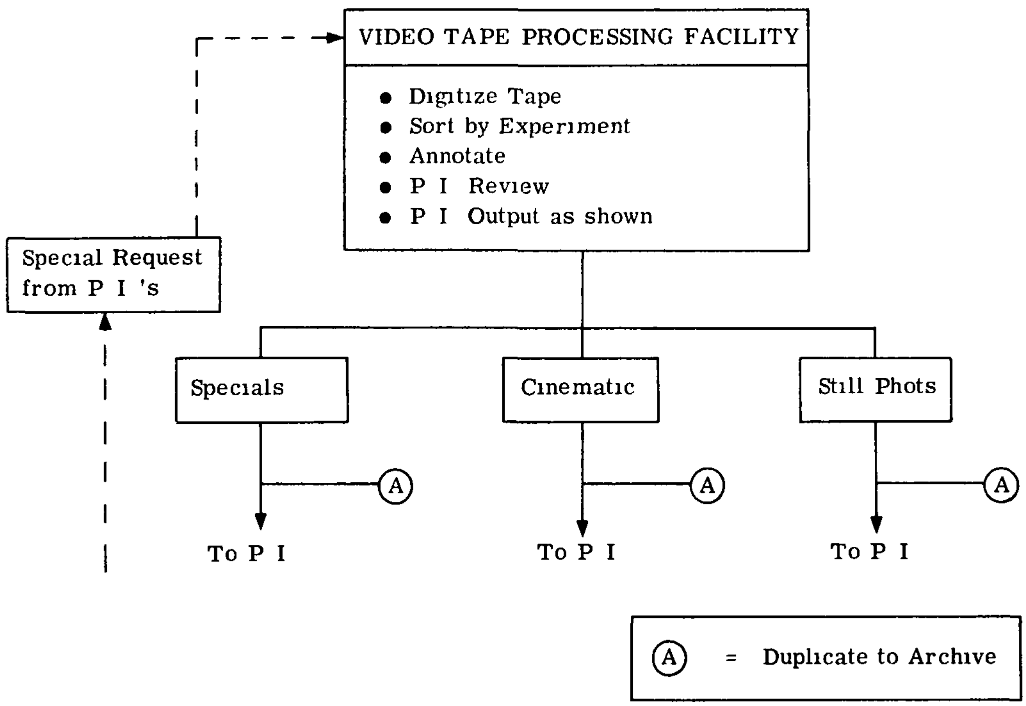


Figure 3. 2-5. Video Tape Processing Flow

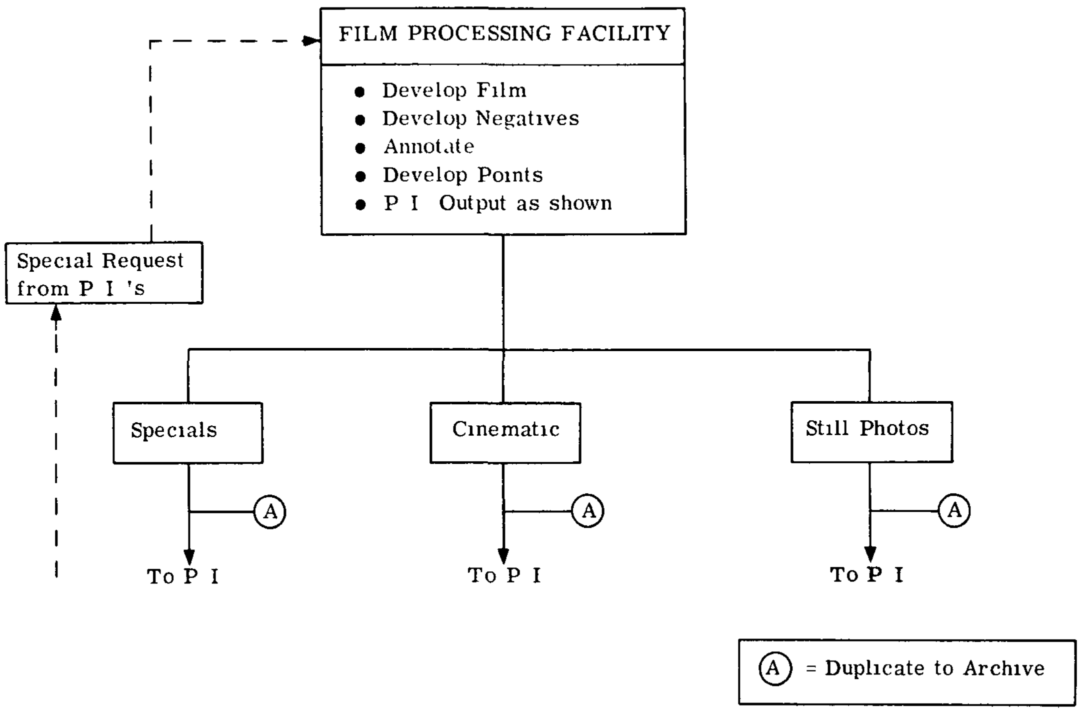


Figure 3. 2-6. Film Processing Flow

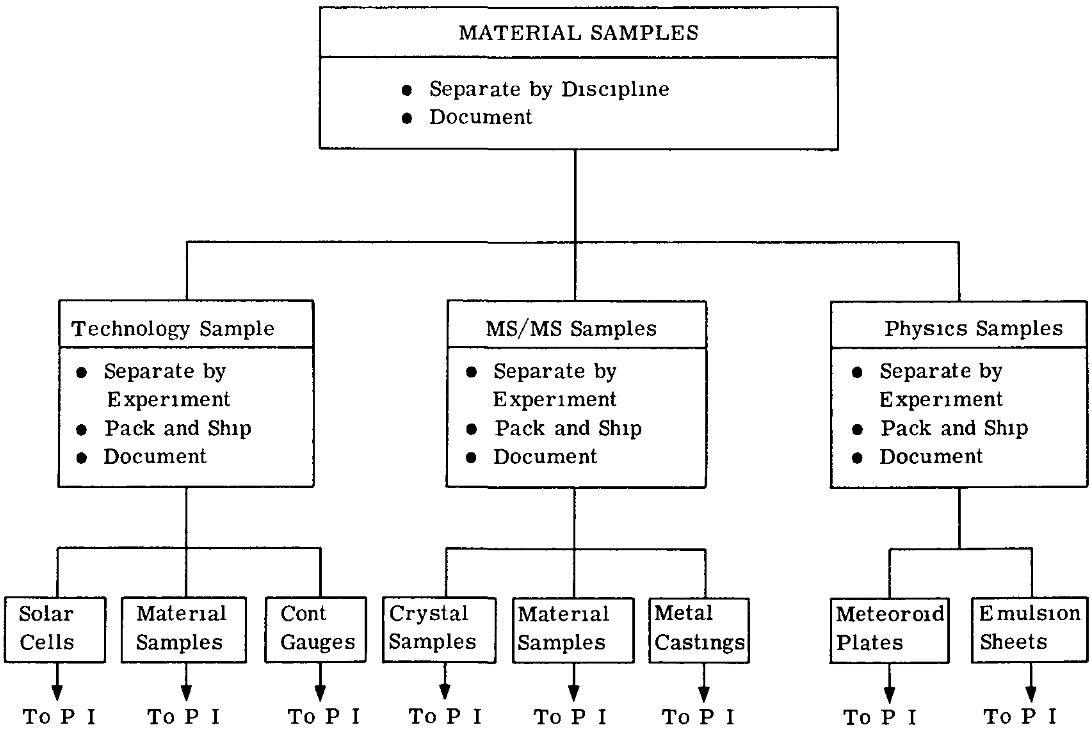


Figure 3. 2-7. Samples Processing Flow

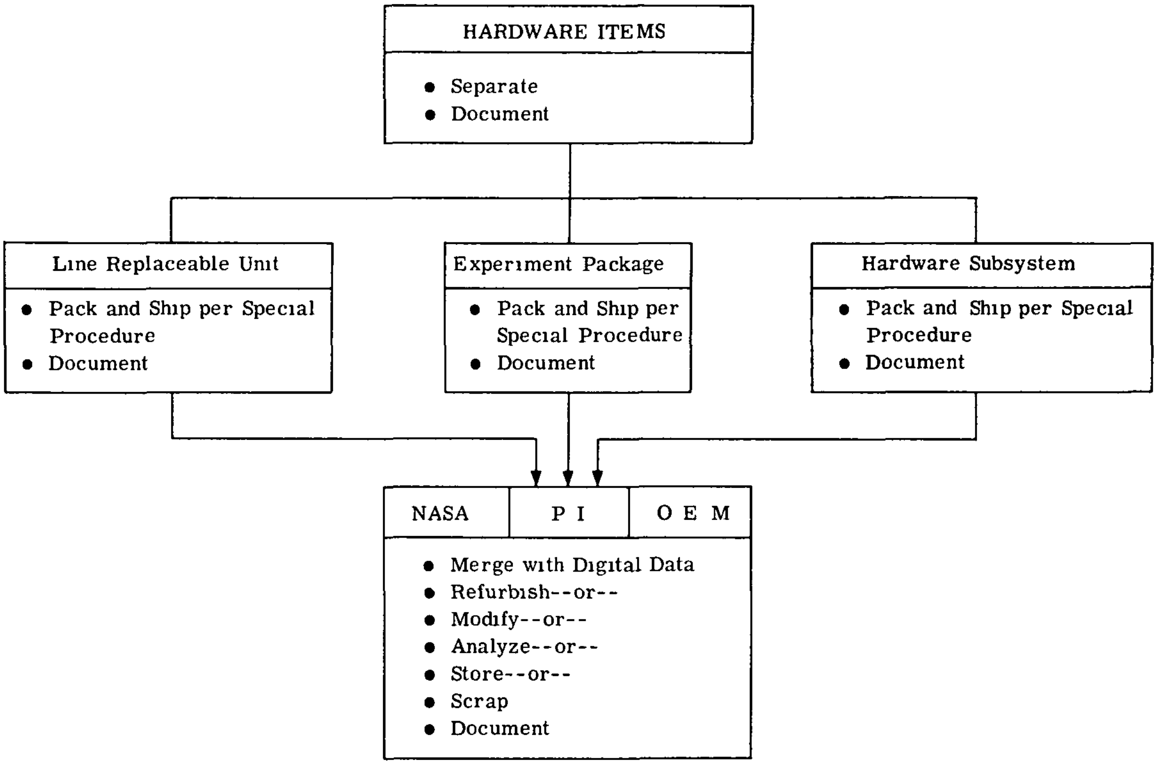


Figure 3 2-8. Hardware Processing Flow

all tapes for a 24-hour period have been replayed through the ground data bus, the intelligence contained therein resides in buffer storage segregated by discipline

The most significant advantage to such a sort-and-merge system is that it is a hardware system and relatively inexpensive It further utilizes hardware that will already have been developed for the onboard system

The most significant disadvantage is that practical consideration precludes a buffer storage capacity in excess of 24 hours of shuttle data This means a 30-day delay from shuttle landing to last tape sort since the tape data will be input at a rate of 24 hours of tape every 24 hours, and the buffer must be unloaded before the next 24-hour period can be initiated

A second option is to input the high density magnetic tape data into a high-speed digital computer and sort-and-merge the data onto computer compatible tapes These computer compatible tapes can then be disseminated to the users as required

The most significant advantage of this second option is that 30 days of data returned via the shuttle can be sorted-and-merged in approximately one-fourth the time required by the first option

The most significant disadvantage is the high cost associated with the sort-and-merge processor

A third option is to sort-and-merge onboard the Space Station all data associated with each specific discipline

The most significant advantages are in avoiding the cost and time involved in sort-and-merge on the ground

The disadvantage is in the additional tapes and tape drives required onboard Since more tapes are involved, the cost of their return is also to be counted

3.2.1.2 Dissemination

Once the sort-and-merge activity is complete the next step in the data flow is dissemination to the user There are several options available as described below

First, consider the data being stored in the 24-hour buffer storage system This buffer can be "unloaded" in several ways Principal Users or User Agencies can, through a leased or dial-up telephone network, "dump" the buffer storage each day An exception to this is the earth resources data whose volume cannot be accommodated over existing or planned high-speed data lines The "daily data dump" can then be maintained at the user or user agency for subsequent processing and/or dissemination

Second way to dump the buffer daily is to place all data on the Television Network presently leased for National Education Television Initial calculations show that less than five hours real time would be required to dump 24 hours worth of data Since NETV is a national network and less than 50 percent utilized, this network could easily provide five hours nonprime time for the dissemination of scientific data

A third option is to dump the buffer storage to adjacent equipment which can generate as many copies on magnetic tape as required and mail or ship these tapes to all cognizant users or user agencies

If a high-speed processor were utilized to generate computer compatible tapes from the shuttle returned high-density tapes, then subsequent dissemination could be made by either leased telephone lines or direct shipment of copies of the tapes as described above

This concept provides for the dissemination of data from Space Station to user or user agency. Sort-and-merge activity is limited to the discipline level (e g , physics, technology, astronomy, etc)

3 2.2 RF BROADCAST TO CENTRAL RECEIVING FACILITY (CRF)

The concept of RF broadcast to a CRF is predicated on the assumption that a Tracking and Data Relay Satellite System (TDRS) will be operational during the 1980-1990 time frame The concept is quite simple since all digital and analog data can be transmitted to the synchronous satellite and relayed to the ground receiver on a real time basis (except for transmission delay times) Once the data arrives at the CRF, it can be automatically sorted by the ground data bus system described above Subsequent dissemination of the data from the buffer storage can also be accomplished as described in the previous concept This concept does not interfere with the real time data requirements of mission management since additional data bus terminals can be programmed to strip out this real time data and route it to the on-line processing system instead of to buffer storage

Dissemination of nontransmissable data (e g , specimens, samples, hardware items, film, etc.) must still be initiated via shuttle delivery to a handling facility, however, approximately 80 percent of the data load is removed from the shuttle resupply module inventory if RF transmission is selected for implementation

3.2.3 RF BROADCAST TO INDIVIDUAL USERS

If an operational TDRS system is assumed, a third concept for consideration involves direct broadcast from Space Station to individual users or user agencies Each user or agency will locate at his facility a receiving station tuned to the TDRS frequency The receiver station includes a data bus terminal or similar code sensitive interface which accepts for recording or direct input to a processor, data from only that specific discipline or experiment of interest

The most significant advantage is in the real time dissemination to the user's processor so that immediate analysis activity can be initiated

The major disadvantages associated with this concept is the cost to implement and operate multiple receiver stations throughout the world This cost could be reduced somewhat by mobilizing many of the receiver stations and deploying them amongst short time users

(NOTE It is appropriate at this time to note that the feasibility of utilizing mobile stations for real time reception of data need not be limited to the above concept A smaller trailer equipment with S-band RF receivers could be located in numerous small countries or even states and receive data from the Space Station directly without relay through the TDRS This approach would be especially attractive for earth resources data wherein the only information required is that being collected while the Space Station is over the local state or country wherein line-of-sight communication is available from the ground station Such an arrangement should be most attractive to states and small foreign countries since the equipment cost is minimum and the flexibility maximum)

3.3 COST INFORMATION DEVELOPMENT

The costs associated with the three concepts above have been estimated and listed in the following paragraphs All costs should be considered as approximations only

3.3.1 WEIGHT/VOLUME CONVERSIONS

Table 3 3-1 reflects the conversion of data specified in bits to data specified in reels of computer compatible tape For this study, a computer compatible tape is defined as 630 bit/cm (1600 bps), 9-track magnetic (8 track of data) 61 meters (2400 feet) in length Each experiment identified in Case 534G of the NASA Blue Books has been converted to either reels of tape or cassettes, magazines, or reels of video tape or cinematic and still film

3.3.2 DIRECT MAIL SERVICE

Direct Mail Service includes all methods of physical transportation of data Figure 3 3-1 is typical of the cost/weight/distance curves used for air express, air freight, and motor freight Current U S Postal charges were used for fourth class parcel post and first class air mail deliveries up to a 70 pound maximum weight No information is provided for rail freight or express since the Space Station data form (i e , magnetic tape) is classified by the railroads as a class 100 item which means the cost would exceed that of air and motor fneght for

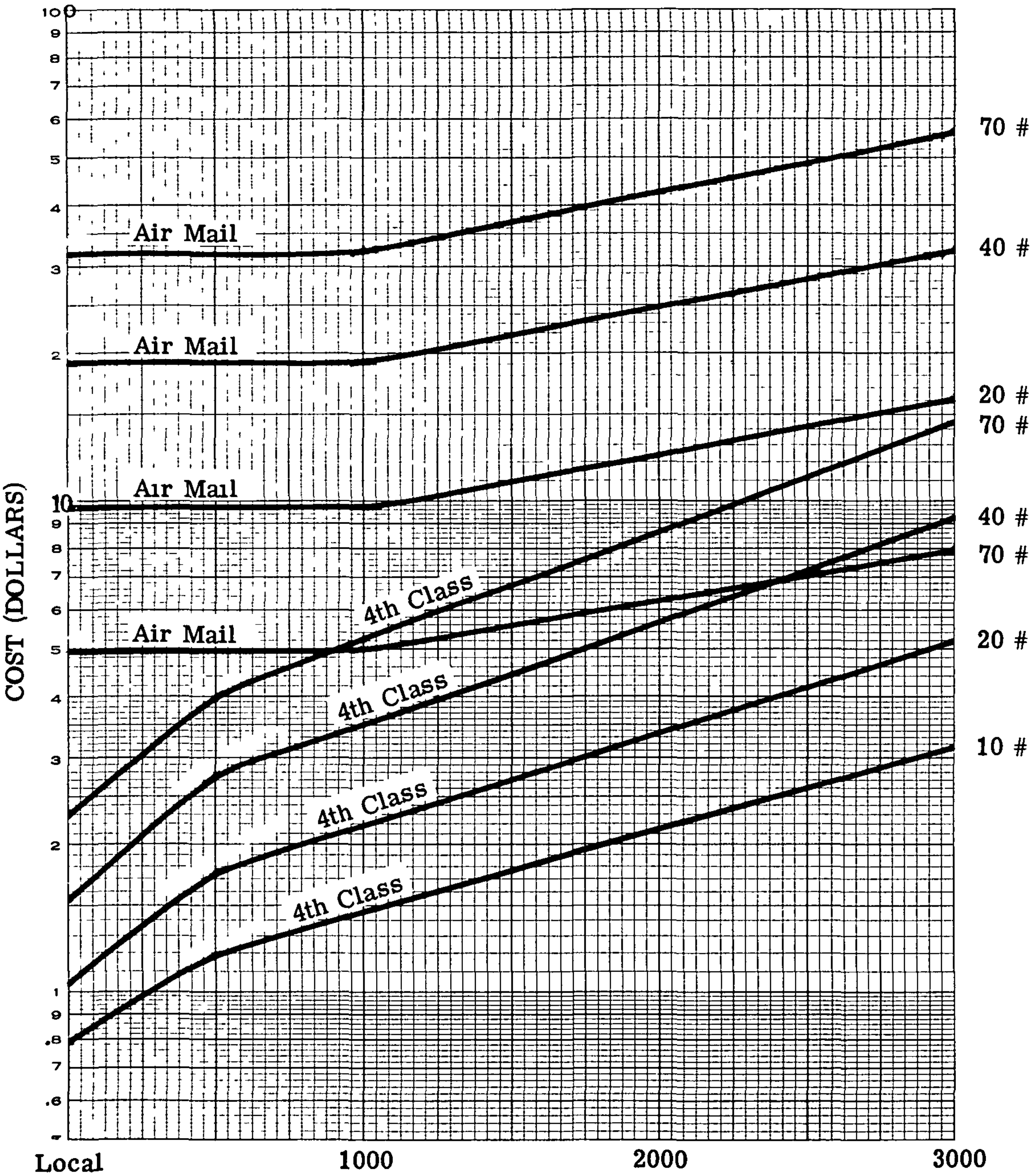


Figure 3. 3-1. Cost/Distance/Weight-1

comparable weights and distances Since both air and motor freight provide faster service, railroad transportation was eliminated from consideration

3.3.3 COMMON CARRIER SERVICE

Electronic data can also be disseminated by either leased line or dial-up service from the AT&T common carrier network. Table 3.3-2 is a monthly cost matrix for leased line service within the United States Table 3 3-3 is a cost matrix for a dial-up line of 50 Kbps capacity A 50 Kbps was selected as the most cost effective transmission rate commensurate with dissemination requirements

3.3.4 MOBILE RECEIVER STATIONS

Implementation of the "RF Broadcast to Individual User" concept required a number of RF Receiver Stations to be located at various locales within the United States Since many of the users require this service for relatively short periods of time (three to six months–depending on experiment duration), an effort was made to make the RF receiver equipment mobile Thus, the same "trailer" could be utilized by various users on a basis coincident with their respective experiment schedules Figure 3 3-2, Mobile Receiver Station, reflects the basic costs associated with equiping a trailer to receive data in the Ku-band, which is the frequency presently specified for the TDRS

3.3.5 SORT-AND-MERGE COST

Sort-and-merge may be accomplished in one of three ways as follows

3.3.5.1 Processor

The cost to perform sort-and-merge, utilizing a dedicated processor system, is detailed in Section 5

3.3.5.2 Ground Data Bus

The cost to implement sort-and-merge, utilizing a ground data bus system, consists primarily of the initial nonrecurring cost for the data bus terminals and the buffer storage units

3.3.5.3 Onboard Sort

The cost to implement sorting onboard the spacecraft consists primarily of five additional tape transports and 20 additional high-density tapes per month

3.3.6 SHUTTLE SERVICE COST

Although the Space Shuttle is considered to be an institutional cost, a charge is assumed for transporting 1,600 pounds of high-density tape to the Space Station each month to be used as a recording medium The latest cost per pound estimate for shuttle payload is $200 Therefore, shuttle return of digital and analog data tapes requires a recurring cost of $320,000 per month for shuttle service

Table 3. 3-1. Weight/Volume Conversion

EXPERIMENT NUMBER	EXPERIMENT NAME	VOLUME (REELS, MAGAZINES, CASSETES, ETC) SHIPPING CATEGORY				
		DIG TAPE	VOICE TAPE	VIDEO TAPE	CINEMATIC	SAMPLES
T-1A	CONTAMINATION MEASUREMENTS	18		26	4	52
T-1B	CONTAMINATION MONITORING	9				
T-3A	ASTRONAUT MANEUVERING UNIT	2	1	7	18	
T-3B	MANEUVERABLE WORK PLATFORM	3		8	6	
T-4A	LONG DURATION SYSTEM TEST	3				1132
T-4B	FLAME CHEMISTRY & LASER EXPERIMENT	4			1	
T-4C	SHORT DURATION SYSTEM TEST	159			32	100
T-5A	TELEOPERATIONS INITIAL FLIGHT	1		9		
ES-1C	EARTH OBSERVATIONS (MINIMUM PAYLOAD)	8000			90	
MS-3A	CRYSTAL GROWTH, BIO & PHYSICAL PROCESSES	20		57		203
MS-3B	CRYSTAL GROWTH FROM VAPOR	7		9		5
MS-3C	CONTROLLED DENSITY MATERIALS	4		19		2
MS-3D	LIQUID AND GLASS PROCESSING	11		5		3
MS-3E	SUPERCOOLING & HOMOGENEOUS NUCLEATION	1		8		2
CN-1B	COMM/NAV RESEARCH GROUP	185			11	
P-1A	ATMOSPHERIC & MAGNETOSCIENCE MODE 1	215		10		
P-1B	COMETARY PHYSICS	1				
P-1C	METEOROID SCIENCE	2			1	
P-1D	THICK METEOROID PENETRATION	1				
P-1E	SMALL ASTRONOMY TELESCOPES	106			1	
P-3C	PLASTIC EMULSIONS					
P-4A	AIRLOCK & BOOM EXPERIMENTS	151			1	
P-4B	FLAME CHEMISTRY & LASER EXPERIMENT	1321			66	
P-4C	TEST CHAMBER EXPERIMENT	15			21	
LS-1A	MINIMUM MEDICAL ESEARCH FACILITY	5			347	
A-4C	SMALL UV SURVEY TELESCOPES	4			4	

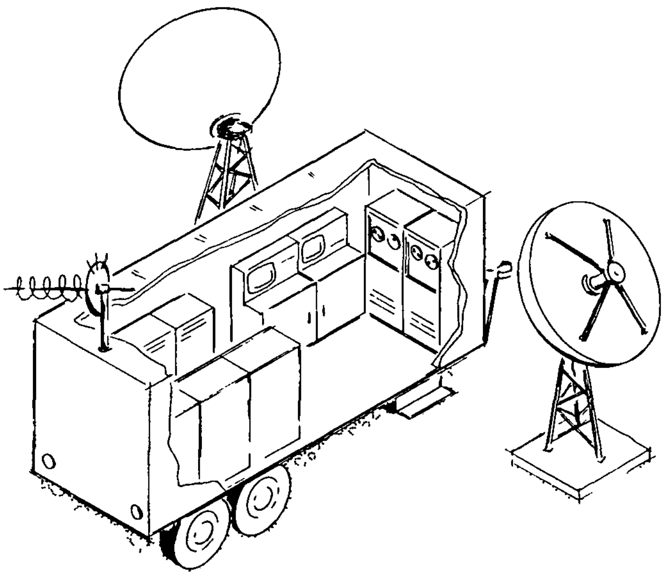
Table 3. 3-2. Leased Line Cost (Monthly)

TRANSMISSION RATE (BPS)	2400	4800	9600	19 2K	40.8K	50K	230K
TIME TO TRANSMIT ONE REEL OF C C TAPE (HRS)	42.6	21 3	10 7	5 32	2.5	2 0	47
MODEM COST/MONTH ($)	115	300	400	425	425	425	650
ONE TIME INSTALLATION ($)	125	250	250	200	200	200	200
DISTANCE (MILES)							
<50	$ 128	$ 128	$ 128	$ 750	$ 750	$ 750	$ 1,500
-100	233	233	233	1,500	1,500	1,500	3,000
-250	458	458	458	3,750	3,750	3,750	7,500
-500	720	720	720	6,375	6,375	6,375	15,000
-1000	1,095	1,095	1,095	10,125	10,125	10,125	30,000
-2000	1,845	1,845	1,845	18,625	18,625	18,625	60,000
-3000	2,395	2,395	2,395	26,125	26,125	26,125	90,000

Table 3. 3-3. Dial-up Data Phone Service

50 Kbps		$275/Term/Mo + 125K
Airline Miles	**Chg/Min**	**Chg/Reel**
0-51	0.50	67.50
51-150	0.80	100.00
151-300	1.25	160.00
301-600	1.75	220.00
601-1200	2.25	280.00
1201-2000	2.75	344.00
2001-over	3.25	410.00

NOTE: 125 minutes required to transmit one reel of computer compatible tape at 50 Kbps



UNIT	TOTAL COST
Data Bus Terminal (3 @ 35K)	$105,000
Ku Transmitter	125,000
Ku Receiver (3 @ 75K)	225,000
30-ft Parabolic Antenna (2 @ 25K)	50,000
Computer Interface	50,000
Display Interface (3 @ 25K)	75,000
Display (3 @ 25K)	75,000
Trailer & Wiring	25,000
SUB TOTAL	$730,000
10 % Contingency	73,000
TOTAL	$803,000

Figure 3. 3-2. Mobile Receiver Station

3.3.7 TRACKING DATA RELAY SATELLITE SYSTEM (TDRS)

The cost of TDRS was assumed to be ınstıtutıonal However, an operatıng cost of $333,000 per month was supplıed by NASA for trade studıes Reference memo from NASA Hq/MF, Subȷect Cost of DRSS, dated September 7, 1971

3.3 8 MAGNETIC TAPE COST

A 30-day quantıty of Space Statıon generated data reduces from approxımately 130 hıgh-densıty tapes to approxımately 12,000 computer compatıble tapes, a blank tape cost of $25, therefore 12,000 tapes cost $300,000 Thıs would be a recurrıng monthly cost

3.3.9 NATIONAL EDUCATION TELEVISION COST

Natıonal Educatıonal Televısıon ıs presently subsıdızed by the Unıted States Government Sınce approxımately 50 percent of the tıme ıs avaılable wıthout ımpact to NETV programmıng, ıt was assumed that through legıslatıon, provısıons could be made to allow thıs network to carry the Space Statıon data durıng off hours at no charge

3.4 COST TRADE STUDIES

Fıgures 3 4-1 through 3 4-3 reflect the costs assocıated wıth each concept In each case, the total cost for a gıven concept ıs the sum of ındıvıdual costs whıch results ın the lowest possıble fıgure Dollar values ın parentheses represent costs assocıated wıth a specıfied functıon but ın all ınstances are not ın the total sınce there ıs a less expensıve method of accomplıshıng the same functıon For example, data returned vıa the Space Shuttle can be sorted-and-merged by eıther ground data bus, by a sort-and-merge processor, or on board the spacecraft The processor approach ıs more expensıve than the data bus system However, the tıme requıred to perform sort-and-merge on a shuttle load of data ıs 30 days for the data bus system compared to 8 days for the sort-and-merge processor By sortıng on board however, the tıme delays are avoıded and at a lesser cost.

The matrıces ın Fıgures 3 4-1 through 3 4-3 reflect all costs, however, the total ıncludes the lesser cost approach (ı e , sort and merge on board)

3.4.1 SHUTTLE RETURN

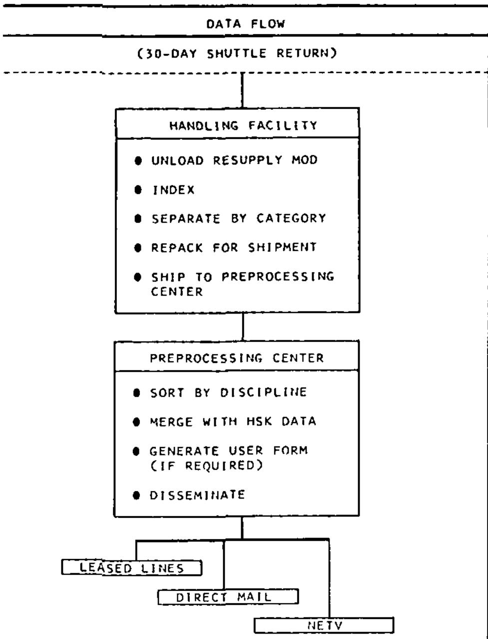
Fıgure 3 4-1 consısts of a functıonal flow dıagram assocıated wıth data returned vıa shuttle plus the recurrıng and nonrecurrıng cost for the varıous functıons. Most of the dollar values are self-explanatory or arbıtrary estımates, however, several ıtems need clarıficatıon as follows

3.4.1.1 Generate User Forms

Thıs ıs the effort requıred to convert the data from the buffer storage unıts to computer compatıble tapes ın multıple copıes for many users. The $300,000 per month materıal cost ıs the charge for a suffıcıent quantıty of blank tapes to provıde copıes to all cognızant users

3.4.1.2 Leased Line Cost

Thıs cost ıs based on the mınımum charge for a leased lıne servıce of 50 kılobıts capacıty operatıng an average dıstance of 1,000 aır mıles



COST		
FUNCTION	RECURRING COST	NONRECURRING COST
OPTIONS		
● SHUTTLE SERVICE 670 KG @ $440/KG (1474 LBS @ $200/LB)	295,000/MO	
● HANDLING FACILITY	2,000/MO	
● SORT AND MERGE		
A BY PROCESSOR		
- HARDWARE		(20,000,000)
- SOFTWARE		(2,000,000)
- OPERATING COST	(32,000/MO)	(200,000)
- FACILITIES		(1,000,000)
- RDT&E		(1 000,000)
B GROUND DATA BUS		
- HARDWARE		(1 100,000)
- OPERATING COST	(1,000/MO)	
- RDT&E		(1,000,000)
C ONBOARD SORT		
- HARDWARE		500 000
- OPERATING COST	25,000/MO	
● DISSEMINATION		
A NETV		
- OPERATING COST	(25,000/MO)	
- HARDWARE		(100,000)
- RDT&E		(100,000)
- GROUND BUFFER	(25,000/MO)	(3,000,000)
B DIRECT MAIL		
- MAIL SERVICE	14,000/MO	
- LABOR	10,000/MO	
- HARDWARE		1,000 000
C LEASED LINE	(3,360 000/MO)	(200 000)
SELECTED FUNCTIONS		
● SHUTTLE SERVICE	295 000/MO	
● SORT & MERGE BY ONBOARD DATA BUS	25,000/MO	500,000
● DIRECT MAIL	24,000/MO	1,000,000
● HANDLING FACILITY	2,000/MO	
SUBTOTAL	346,000/MO	
MANAGEMENT COST (10%)	35,000/MO	1,500,000
TOTAL	1 000/MO	1,500,000

Figure 3. 4-1. Concept A - Shuttle Return

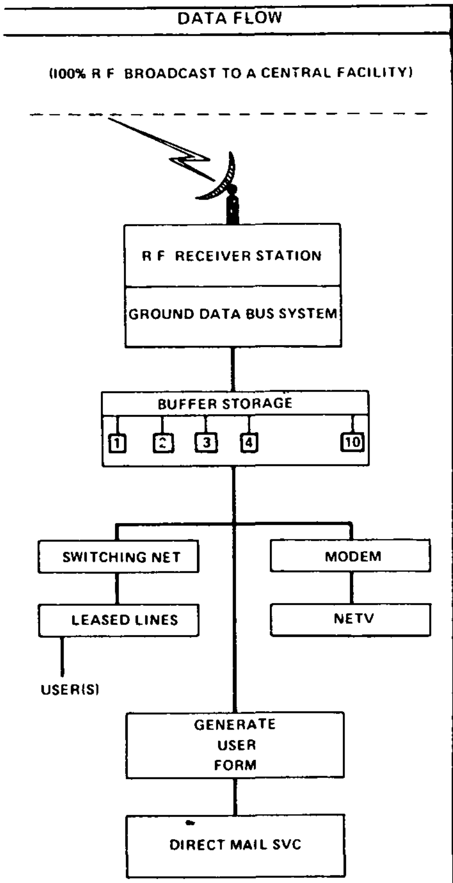
3.4.2 RF BROADCAST TO A CENTRAL FACILITY

The format for this cost analysis is similar to the previous concept and is detailed in Figure 3 4-2 The following notes address specific points in the referenced figure.

- The operating cost for TDRS was supplied by NASA.
- The assumption that NETV Network cost will be zero requires concurrence from the FCC and AT&T

3.4.3 RF TRANSMISSION TO INDIVIDUAL USERS

Figure 3 4-3 which depicts RF transmission to individual users or user agencies requires the following explanations.



	COST	
FUNCTION	RE CURRING	NON RECURRING
OPTIONS		
RECEIVER STATION		INSTITUTIONAL
OPERATING COST	333,000/MO*	
GROUND DATA BUS		
HARDWARE		600 000
RDT & E		500 000
OPERATING COST	1 000/MO	
BUFFER STORAGE		
HARDWARE		2,500,000
RDT & E		500,000
OPERATING COST	25 000/MO	
DISSEMINATION		
LEASED LINE COST	($3 36M/MO)	(200,000)
NETV DISSEMINATION		
HARDWARE		(100,000)
RDT & E		(100,000)
OPERATING COST	($25 000/MO)	
DIRECT MAIL	14 000/MO	
LABOR	10 000/MO	
SELECTED FUNCTIONS		
RF TRANSMISSION	333,000/MO	
GROUND DATA BUS	1,000/MO	1,100 000
BUFFER STORAGE	25 000/MO	3 000,000
DIRECT MAIL	24,000/MO	
SUBTOTAL	383,000/MO	4,100 000
MANAGEMENT COST (10%)	38,000/MO	
TOTAL	421 000/MO	

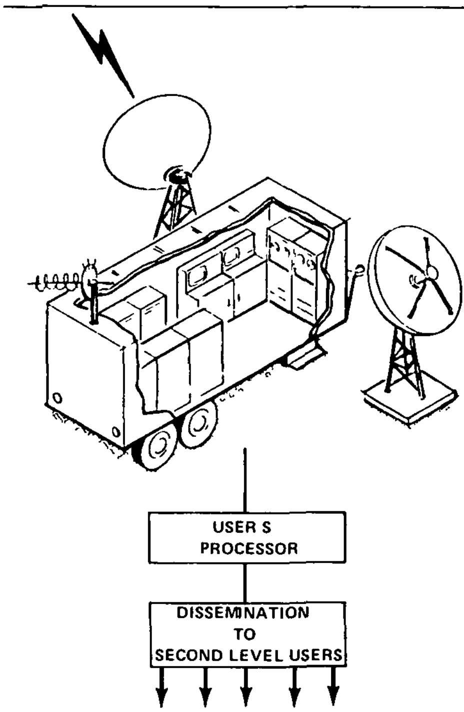
*TDRS OPERATING COST SUPPLIED BY NASA

Figure 3. 4-2 Concept B - RF Broadcast to a Central Facility

3.4.3.1 Mobile Trailers

- It was assumed that 40 trailers would be sufficient to address the experiment schedules planned for the Space Station
- It was assumed that 20 of the 40 trailers would be moved each month at a cost of $2,000 per move
- Operating cost was based on two men per shift for three shifts, 26 days per month

DATA FLOW



FUNCTION	COST: RECURRING COST	COST: NON- RECURRING
RECEIVER STATION –HARDWARE –RDT & E –OPERATING COST	 (25 000/MO/TR)	 $800 000/TRAILER 1, 000 000
ASSUME 40 TRAILERS		
HARDWARE RDT & E OPERATING COST TRAILER LOGISTICS EXPENSES	 *1 000, 000/MO 40 000/MO	32, 000 000 1 000 000
DISSEMINATION TO SECOND LEVEL USERS		
–GENERATE USER FORM –MAIL SVC	*150 000/MO * 7 000/MO	
SUB- TOTAL	1 197 000/MO	33 000 000
MGMT COST (10%)	120 000	
	1 317 000/MO	33 000 000

* ESTIMATED USER COSTS FOR OPERATION & SECOND LEVEL DISTRIBUTION

Figure 3. 4-3. RF Transmission to Individual Users

3.4.3.2 Secondary Dissemination

- It was assumed that the equipment required to generate secondary user data forms would be in the user or user agencies' present capital equipment inventory, therefore, no nonrecurring cost is associated with this matrix

- The recurring cost associated with secondary user dissemination includes operating cost and material cost for multiple tape generation

3.4.4 COST SUMMARY COMPARISONS

Figure 3 4-4 is a comparison chart for the three basic concepts based on economics with no consideration for dissemination time requirements.

CONCEPT	CUMMULATIVE COST (YEARS)				
	1	3	5	7	10
A - SHUTTLE RETURN					
• Non-Recurring	1.5M				
• Recurring	4 6M				
• Total	6.1M	15.3M	24 5M	33.7M	47.5M
B - RF TRANSMISSION					
• Non-Recurring	4 1M				
• Recurring	5 1M				
• Total	9 2M	19 4M	29 6M	39 8M	55.1M
C - RF BROADCAST					
• Non-Recurring	33 0M				
• Recurring	15.8M				
• Total	48 8M	80 4M	112M	143 6M	191M

Figure 3. 4-4. Summary Cost Comparisons (Based on NETV Dissemination)

3.5 DISSEMINATION TIME REQUIREMENTS

Figure 3 5-1 is a matrix of time required to disseminate data to the user or user agencies for all concepts Functions and times are self-explanatory

3.6 CONCLUSIONS

As a result of this study, the following conclusions regarding the dissemination of data from space programs are made

- Dissemination is significantly impacted by sort-and-merge time required for shuttle returned data, when this function is ground based
- Utilization of Shuttle return, coupled with direct mail service, is the most cost effective concept, by a small margin over RF return to a central site
- Shuttle service is required for return of samples, specimens and film
- RF return is required for real and near real time data
- Today's technology is adequate to meet the data dissemination requirements 1980-1990

DATA TYPE BY CONCEPT	UNLOAD SHUTTLE (DAYS)	INDEX TAG & REPACK (DAYS)	SHIP TO CENTER (DAYS)	SORT & MERGE (DAYS)	PROCESS V T & FILM (DAYS)	GENERATE USER FORM (DAYS)	SHIPPING TIME TO USER	TOTAL TIME (DAYS)
DIGITAL DATA								
CONCEPT A	1/2	1 1/2	1	8	---	2	1 4	11 17
CONCEPT B	---	----	---	---	---	---	---	WITHIN 24 HRS
CONCEPT C	---	---	---	---	---	---	---	REAL TIME
FILM DATA								
CONCEPT A	1/2	1 1/2	1	---	8	5	4	20
*CONCEPT B	---	---	---	---	8	5	4	17
*CONCEPT C	---	---	---	---	4	3	2	9
VIDEO DATA								
CONCEPT A	1/2	1 1/2	1	2	2	8	4	19
CONCEPT B	---	---	---	2	2	1		5
CONCEPT C	---	---	---	---	2	2	---	4
SAMPLES & SPECIMENS								
CONCEPT A	1/2	1 1/2	---	---	---	---	4	6
EMULSIONS								
CONCEPT A	1/2	1/2	---	---	---	---	1	2
HARDWARE ITEMS								
CONCEPT A	1/2	1 1/2	---	---	---	---	4	6

*ASSUMES SATISFACTORY RESOLUTION AND QUALITY

Figure 3. 5-1. Data Dissemination Times

INTERACTIVE USER INTERFACE 4

4.1 INTRODUCTION

4.1.1 SCOPE

The intent of this task was, initially, to define an interactive user interface and to explore means of implementation Early in the study, this scope was expanded to include a preliminary measure of the ability of the interactive mode to reduce data flow This was judged to be of significance since the sizing of the ground data flow system is directly dependent on the amount of data flow

4.1.2 STUDY APPROACH

This study assumed a knowledgeable and competent technician onboard the spacecraft and the experimenter on the ground at some facility with equipment to carry out interaction The effort was directed toward defining required equipment, the best location for that equipment, approximate costs associated with that equipment, and the derived benefits from interaction

In order to define the impact of interaction, an operational analysis was performed to summarize interaction requirements This analysis utilized the general experiment requirements defined in Section 2, Requirements Analysis, and specific requirements from ERTS Several interface control methods were conceived and their impact on the payload Information Management System was assessed Trade studies were performed to determine a cost effective information management concept

4.2 OPERATIONAL ANALYSIS

4.2.1 OPERATIONAL EXAMPLE

An analysis of the ERTS experiment, Figure 4 2-1, indicates some real savings by providing interaction Only eighteen minutes of data per day are required to provide all the required information for the U S A Consequently, by scheduling and control of the experiment through a command link, a reduction on the order of 100 to 1 is obtained (18 minutes instead of 1440 minutes) On receipt of data, the data center, in this instance GSFC, will send a few black and white pictures over slow speed facsimile to typical users After scanning these pictures, users forward requests to the data center for data only from specific areas of interest This interaction delays the processing by up to 10 days but reduces the data processing load by additional factors of 10 to 100. Real time interaction could eliminate the 10 day delay and might reduce the data processing load even further The total data load reduction on ERTS from interaction is on the order of 10^3 to 10^4 to 1

For this example, it can be seen that interaction of this type provides the following improvements in experiment operations

- Data quality is improved
- Experiment operation time can be reduced
- The overall data load can be reduced
- The lag time between data taking and meaningful results can be reduced

- The user becomes more involved with his experiment
- The Space Station operational efficiency is increased

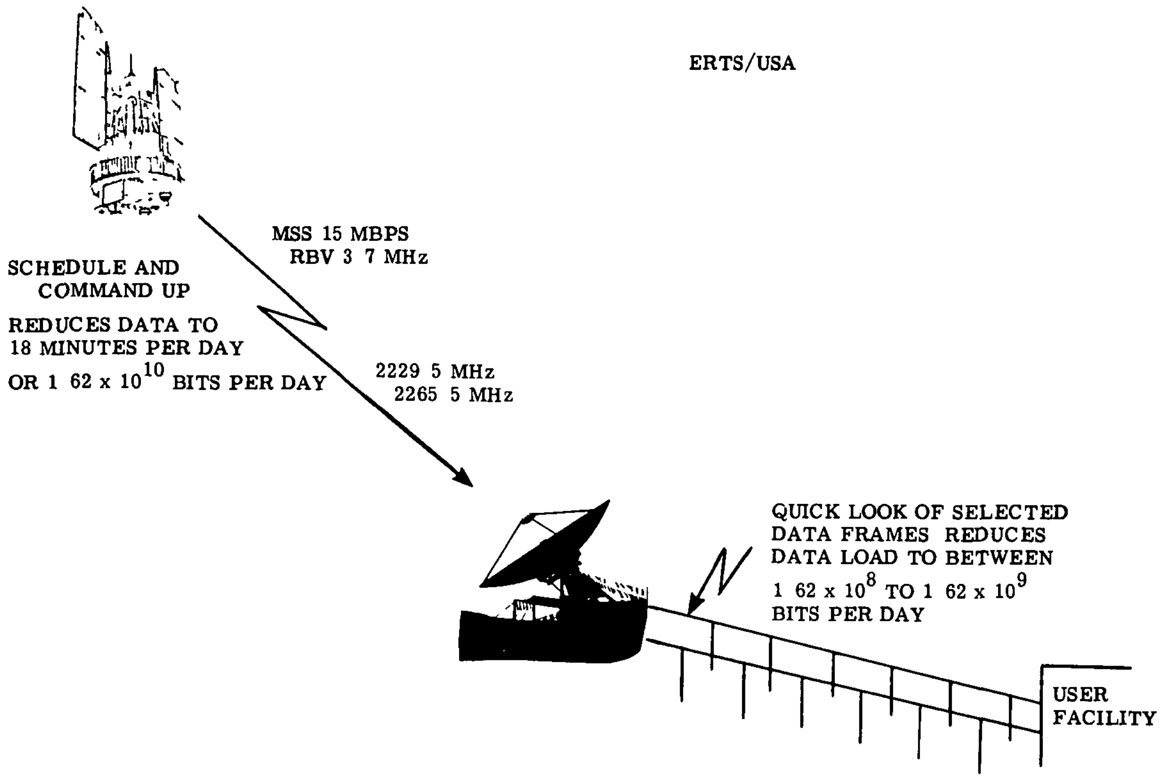


Figure 4. 2-1. ERTS Experiment

4.2.2 PROCEDURE

Investigation into the operational example was guided by a series of questions aimed at forcing quantification in answers These questions are shown in Figure 4 2-2, along with the results of the ERTS operational example, and extrapolations into the ES1-A

4.2.3 INTERACTION EVALUATION

Interaction between Space Station astronauts and Principal Investigators should be quite beneficial The Alabama users ERTS data have shown a significant savings in data processing through interaction involving quick look scanning for desirable data selection Interviews with other Principal Experimenters and detailed investigation of data load reduction factors shown in Figure 4 2-3. These factors are judged to be from interaction alone and are in addition to the reduction from standard data reduction techniques The data loads in

Operational Analysis	Operational Example	ES1-A
1 What is the problem to be solved?	Crop and Forestry Identification, inventory, diagnosis etc	Land use mapping
2 How much data is needed to solve the problem?	3 24 x 10^8 bits/day once/ month (data base)	3 4 x 10^{10} bits/day
3 What data is needed to interact?	3 24 x 10^6 bits/day each 10 days (specific areas)	1 35 x 10^{10} bits/day
4 What decisions are made in interaction?	Regions of interest, data quality	Regions of interest, quality
5 What control over experiment?	On-off, schedule, filter, frame	Equipment adjustment, sensor selection, target selection, scheduling
6 What impact on SS/ Ground operations?	10 day delay–need facsimile line	Need TV down link, voice up
7 What time available?	Days	Minutes during orbit and in between
8 Can interaction reduce data?	Yes	Yes
9 Can interaction improve quality?	By eliminating unuseable data	By experiment adjustment and eliminating unuseable data
10. How much analysis during interaction?	Manual, visual interpretation	Correlation, computer assisted
11 Impact on System Loading?	100 - 1 reduction	4 - 1 reduction conservative estimate (screening, need assessment, and scheduling)
12. How much experimentor's time?	Up to 3 days/month	Full time control data for multiple users

Figure 4. 2-2 Operational Investigation

DISCIPLINE	REDUCTION FACTOR	PRESENT DATA LOAD	REDUCED DATA LOAD
LIFE SCIENCES	20 1	5 DIGITAL	1 DIGITAL
EARTH RESOURCES	2 1 TO 10 1	8000 DIGITAL	800 TO 4000 DIGITAL
ASTRONOMY	1 1	4 DIGITAL	4 DIGITAL
PHYSICS	4 1	2811 DIGITAL	703 DIGITAL
TECHNOLOGY	2 1	199 DIGITAL 50 VIDEO	100 DIGITAL 25 VIDEO
MATERIAL SCIENCES	10 1	43 DIGITAL 98 VIDEO	5 DIGITAL 10 VIDEO
COMM/NAV	1 1	185 DIGITAL	185 DIGITAL
	TOTAL	11,247 DIGITAL 148 VIDEO	1,798 DIGITAL 35 VIDEO

Figure 4 2-3. Data Load Reduction Through Interaction

Figure 4 2-3 represent the amount of equivalent 635 bits/cm (1600 BPI), 9 track, digital reels per month initially calculated for shuttle return from the Space Station The presented data loads represent ISS schedules By applying the reduction factors from interaction to these loads, a total reduction of approximately six to one can be realized It can be seen that a concentrated effort in either Earth Resources or Physics (Astronomy for GSS) resulting in small reduction in those areas, produces more meaningful results than large reductions in other disciplines Efforts should be made to maximize interaction in those disciplines

4.3 INTERACTION REQUIREMENTS

4.3.1 INTERACTION CLASSIFICATION

In order to derive the requirements for interaction, each experiment (or discipline) has to be categorized with respect to the timeliness of received data and the urgency of control To facilitate discussion of various interaction requirements, the degrees of control are arbitrarily categorized as shown in Table 4 3-1. Real time control requirement with real time data

transmission is assigned a Type I control classification while redirection from shuttle returned data is class VI

Table 4. 3-1. Interaction Classification

	(Near) Real Time Control	Delayed Control	Redirection
(Near) Real Time Data Transmission	I	II	III
Delayed Data Transmission		IV	V
Shuttle Return Data			VI

An analysis of each of the seven disciplines indicates that multiple classes of control are involved in a number of experiments. The control requirements for each discipline are shown in Table 4 3-2 For most experiments, Type I control is required only during initial setup and

Table 4. 3-2 Interaction Control Classification

Discipline	Interaction Control Class
Life Sciences	Video - I Digital - V
Technology	I and III
Earth Resources	I, IV and V
Physics If something unexpected occurs, real time and delayed data required for statistical analysis Turn around required in 2 or 3 days	I, II and V
Material Sciences	II
Astronomy	Solar - I Stellar - IV

calibration This enables the experimenter to make the quick look determination of whether the data is valid and the experiment is operating properly before taking immense amounts of invalid data After setup, only occasional monitoring is required to ensure continued proper operation This interaction falls in the Class II, III, and IV categories

4.3.2 INTERACTION REQUIREMENTS

The data transmission loads to satisfy experiment interaction requirements are shown in Table 4 3-3 Except where specially defined, the data requirements for ISS and GSS remain

Table 4. 3-3. Interaction Data Requirements

Discipline	Down Link		Up Link
	Digital	Video	
Life Science	12 KBPS (D)	4 MHz (R. T.)	Audio (R. T.)
Technology	60 KBPS (R. T.)	10 MHz (R. T.) ISS 8 4 MHz (R. T.) GSS	Audio (D) ISS Command Link (R. T.) on GSS
Earth Resources	0. 5 MBPS (R. T.) 2. 25 x 10^9 BPO (D)		Slo-Rate Digital (D) Audio (R. T.) Audio (D)
Physics	12 KBPS (R. T.)		Audio (R. T.), (D)
Comm. /Nav.	60 KBPS (R. T.)		Experiment RF Link Only
Material Science	10 KBPS (R. T.) 6. 7 x 10^7 BPD (D)	3. 3 MHz (R. T.) ISS 3. 3 MHz (D) ISS 10 MHz (R. T.) GSS 10 MHz (D) GSS	Audio (R. T.), (D)
Astronomy	500 BPS (R. T.) ISS 2 MBPS (R. T.) GSS	None on ISS 2. 9 MHz (R. T.) GSS 3 3 MHz (R. T.) GSS	Slo-Rate Digital (D) Audio (D) Stellar World wide voice net to mission control, R. T. audio to space station for solar

essentially the same. (R T) signifies a real time transmission requirement and (D) stands for allowable delayed transmission It can be seen that the video down link transmission requirements involve a 10 MHz bandwidth RF link for both ISS and GSS It may be possible to time share this link between the Technology and Material Sciences If not, two video links would be required since the number of simultaneously operating experiments requiring interaction affects data transmission requirements.

A time line of experiment operations is shown in Figure 4 3-1 for the peak day for both ISS and GSS. ISS requires a maximum of two Class I interaction experiments with a maximum of four simultaneous experiments during the peak day

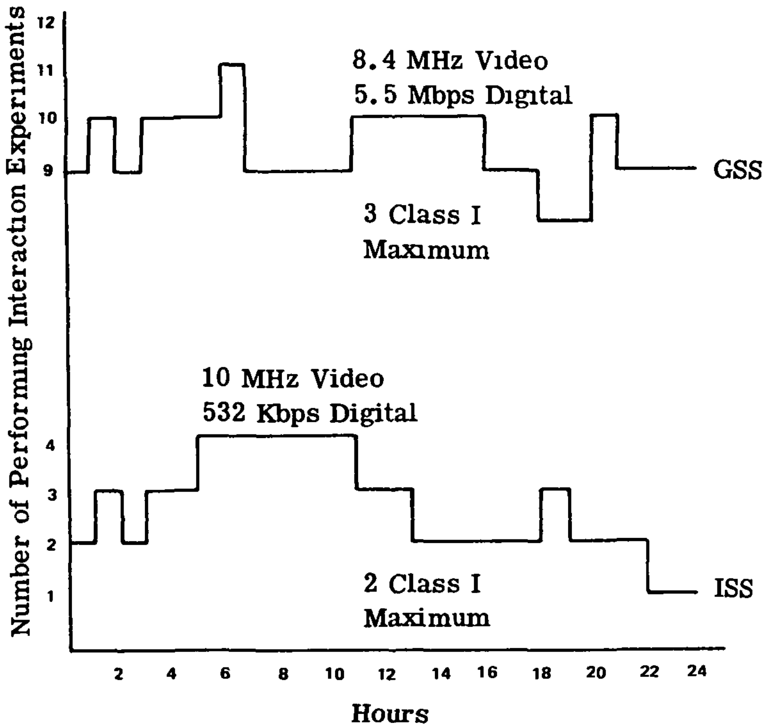


Figure 4.3-1. Interaction Experiment Operation

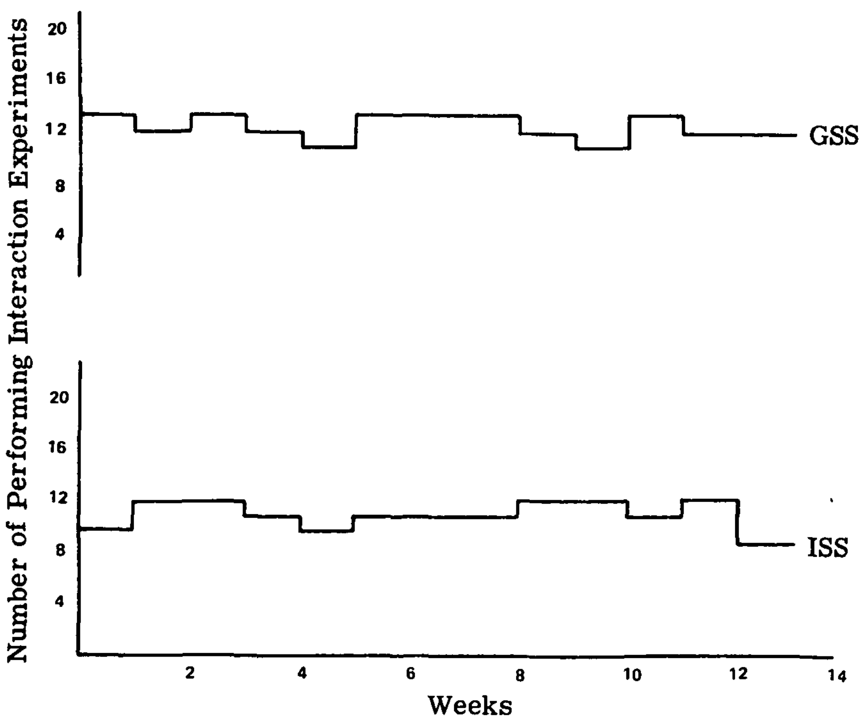


Figure 4.3-2. Weekly Interaction Experiment Operation

Figure 4 3-2, a time line of experiment operations over a three month period, shows a maximum of four simultaneous experiments during any week This does not denote simultaneous operation, however, and only four experiments are conducted simultaneously on ISS. The GSS time lines indicate a maximum of eleven simultaneous experiment operations during the peak day and a total of thirteen conducted on a week to week basis.

From Table 4 3-3, it can be seen that the major RF requirements involve the down link system The up link requirements consist of only a slow speed digital channel and a real time audio link for voice communications between astronaut and experimenter While no one is willing to specify the need for an up link TV, most experimenters mention this convenience and would utilize this capability if it existed

Table 4.3-4 contains the power budgets associated with a synchronous satellite to ground RF link It can be seen that meeting the down link T.V. requirement with TDRS capability

Table 4. 3-4. RF Power Budget T.V. Downlink K_u Band

Ground Receiver Sensitivity	-	103 dbm
6 MHz Bandwidth, 3 db Noise Figure		
Required Signal to Noise Ratio	+	34 db
Required Received Signal Power	-	69 dbm
Satellite Transmitter Power (10 Watts)		40 dbm
Satellite Antenna Gain	+	42
5 Ft Diameter Dish Less Circuit Losses		
Space Loss	-	208 db
Ground Antenna Gain	+	58 db
30 Ft Diameter Dish Less Circuit Losses		
Received Power	-	68 dbm
Signal Margin		1 db
Satellite Receiver Sensitivity	-	100 dbm
6 MHz Bandwidth, 6 db Noise Figure		
Required Signal to Noise Ratio		34 db
Required Received Signal Power	-	66 dbm
*Ground Transmitter Power (50 Watts)		47 dbm
Ground Antenna Gain		58 db
30 Ft Diameter Dish Less Circuit Losses		
Space Loss	-	208 db
Satellite Antenna Gain		42 db
5 Ft. Diameter Dish Less Circuit Losses		
Received Signal Power	-	61 dbm
Signal Margin		5 db

*Transmitter Power could be reduced to 20 watts and still meet S/N requirements.

involves at least a thirty-foot diameter parabolic antenna on the ground Once this is provided, only an additional twenty to fifty watt transmitter at the ground RF station is required to establish uplink television The Tracking and Data Relay Satellite characteristics are used in the power budget calculations Figure 4 3-3 shows the required communication channels to handle the interaction data transmission requirements and includes the optional uplink T V channel Table 4 3-5 shows the power budgets associated with this uplink

In order to make meaningful decisions, the experimenter has to be provided with some processing capability The real time or near real time processing requirements for interaction involve sorting, formatting, conversions to engineering units, and display controls The digital processing requirements are shown by discipline in Table 4 3-6

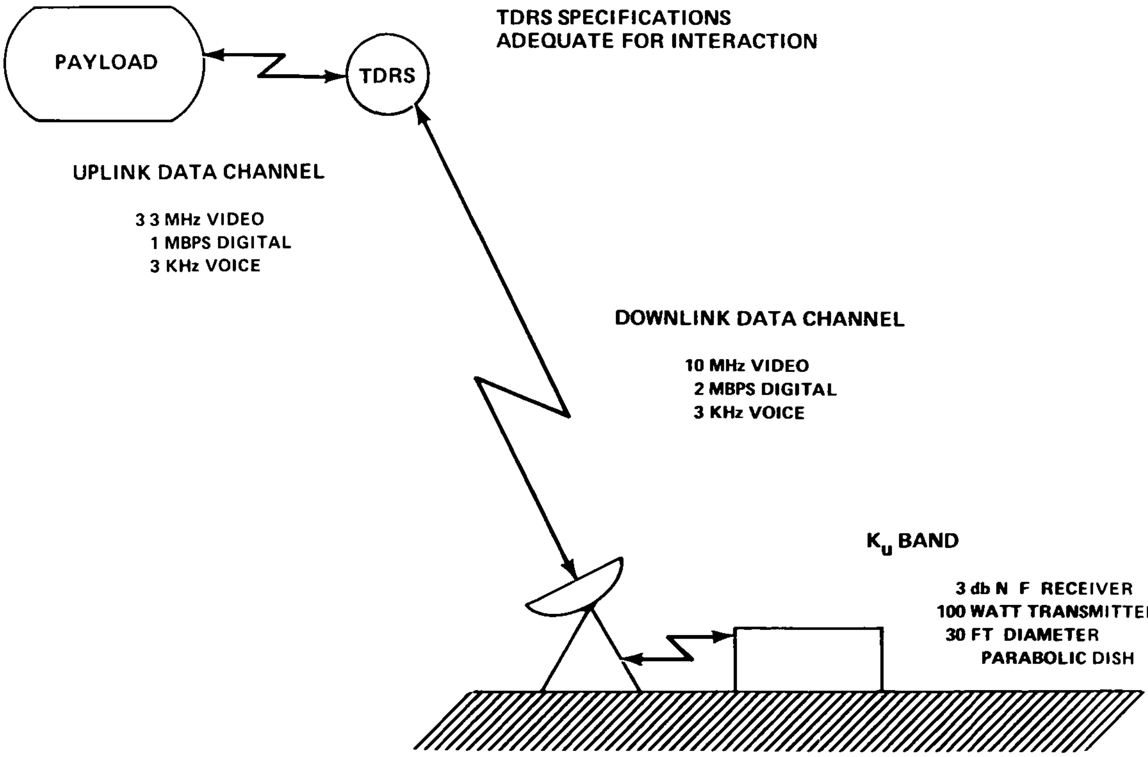


Figure 4. 3-3. Interaction Communications

4.4 INTERACTIVE USER INTERFACE CONCEPTS

In order to realize the benefits of interaction, the Principal Investigator has to maintain contact with the technician aboard the spacecraft carrying his experiment As shown in previous sections, this communication can take several forms, from merely an audio link to a wideband T V and high speed digital data links Two major questions arose during the conceptual design of an interactive system

Table 4.3-5. RF Power Budget T V. Uplink K_u Band

Satellite Receiver Sensitivity	-	100 dbm
6 MHz Bandwidth, 6 db Noise Figure		
Required Signal to Noise Ratio		34 db
Required Received Signal Power	-	66 dbm
*Ground Transmitter Power		47 dbm
Ground Antenna Gain		58 db
30 Ft Diameter Dish Less Circuit Losses		
Space Loss	-	208 db
Satellite Antenna Gain		42 db
5 Ft Diameter Dish Less Circuit Losses		
Received Signal Power	-	61 dbm
Signal Margin		5 db

*Transmitter Power could be reduced to 20 watts and still meet S/N requirements

Table 4 3-6. Interaction Processing Requirements

Discipline	Digital Processing Requirements
Life Sciences	Sort, merge, conversion to engineering units, format, display
Technology	Sort, merge, convert to engineering units, format and display
Earth Resources	Sort, merge, correlate image data with pointing data, format for vidicon display
Physics If something unexpected occurs, real time and delayed data will be required for statistical analysis Turn around required within 3 days	Analysis of particle signatures, sort, merge, conversion to engineering units, D/A conversions, format for X - Y displays
Material Sciences	Sort, merge, conversion to engineering units, format, display, correlate digital with T V data
Astronomy	<u>Stellar</u> - Sort, merge, convert to engineering u units, correlate data with pointing data, display in graphical form <u>Solar</u> - Sort, merge, line splitting, doppler corrections - reaction time in 10's of min
C/N	No digital processing required

1. Where is the Principal Investigator best located for interaction, at his own location or a central facility?

2. What type of control is required to facilitate interaction but yet prevent unnecessary interruption to space station personnel thereby reducing operating efficiency?

Two such concepts are discussed in the following sections, a central facility versus remote user locations and single point control versus shared control. A third concept of control is discussed where a central facility shares control with the space station.

4.4.1 CENTRAL FACILITY VERSUS REMOTE USER SITES

The benefits of locating the interactive facility either at a central facility or at the users site can be assessed with respect to the following criteria

- Interaction capability
- Ease of control
- Flexibility
- Ease of expansion
- Response time
- Initial cost
- Operational costs

The matrix used for this trade study is shown in Figure 4.4-1. The overall results are quite close with neither concept having a clear cut advantage over the other. The central facility has a slight edge. The central facility can provide more equipment for the same cost since the facility would be used by all experimenters. However, the initial cost of the central facility would be greater since each user could utilize some equipment already available. Controlling the amount of interaction would be much easier at a central facility since single point control could be enacted. Space Station to ground station special operation could be utilized much like an overseas telephone operator complete with a priority list based on prior schedules. This advantage may also be a disadvantage however, since this would tend to limit the amount of interaction and principal investigator involvement.

Examination of the trade matrix reveals operating costs to be the major difference in facility locations. The remote facility concept has a major disadvantage which tends to increase operating costs to an unreasonable level. This involves the use of the video down link. For video to be broadcast directly to the remote facility from the TDRS, the antenna pointing system of the TDRS becomes extremely complex. The TDRS antenna system provides a 344 mile-diameter circle of RF coverage. Since up to eleven experimenters may be interacting simultaneously, up to eleven antennas would have to be pointed in different directions depending on their separation. These pointing directions would have to be programmed in advance since the experimenters would change from week to week. As an alternative, the TDRS could broadcast to two central receiving stations and the user could lease telephone lines, on a monthly basis, for communication contact with the TDRS. In addition to the

EVALUATION CRITERIA	CENTRAL FACILITY			REMOTE FACILITY		
	Weight	Rating	Total	Weight	Rating	Total
Interaction Capability	10	10	100	10	6	60
Ease of Control	8	10	80	8	6	48
Flexibility	5	5	25	5	10	50
Ease of Expansion	3	8	24	3	10	30
Response Time	6	5	30	6	10	60
Initial Cost	9	5	45	9	10	90
Operating Cost	10	10	100	10	1	10
TOTAL			404			348

Figure 4. 4-1. Central Facility Versus Remote Facility

cost of the receiving stations, the monthly lease costs of these lines (with video bandwidths) would average $52,500 per user (based on an average distance of 750 miles to each user and $70 00 per mile-month for video lines) Eleven users per month would then represent an operating cost for the leased lines alone of $577,500 per month This cost is more than eighty times the travel costs associated with eleven principal investigations at a central facility each month This would be approximately $7150 per month based on $15 per day per diem and an average cost of $200 travel fare Consequently, the central facility for interaction seems to be the reasonable choice unless technical difficulties associated with T V and/or wideband data communications from TDRS to remote locations can be overcome

4.4.2 SINGLE POINT VERSUS SHARED CONTROL

The control concepts considered in this investigation are shown in Figure 4 4-2

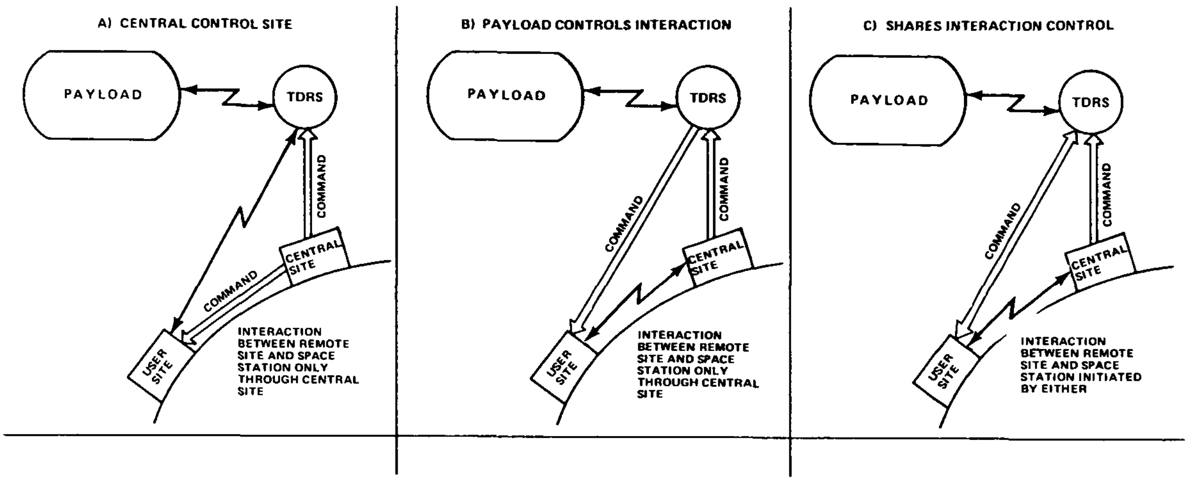


Figure 4 4-2. Interaction Control Concepts

Concept A involves single point control located in a central receiving facility In this instance, all control is exercised by the central facility This concept allows communications (T V and/or audio) between the user and the payload either directly through TDRS or indirectly through the central site depending on antenna pointing capability of TDRS as discussed in Section 4 4 1 The user site may either be located at the central facility or at a remote site However, for the purposes of this study, it is assumed the user is at a central facility in keeping with the conclusions of Section 4 4 1 The single point control center will require a communication switching center or separate links capable of handling four experimenters in ISS and 11 in GSS almost simultaneously The video links should be time shared while the audio links can be frequently multiplexed using standard telephone techniques

Concept B utilizes both the Space Station and a central control point performs coordination tasks and scheduling in conjunction with the Space Station Space Station crew members have the capability of initiating contact with the experimenters without passing through a single point control center For the space to ground link, the actions required would be much like a standard dial-up phone call However, the ground to space link, except when initiated by an astronaut would be subject to the same constraints as Concept A This has the advantages of increased interaction and decreased response time to astronaut technical problems This concept does increase the amount of astronaut activity by increasing his scope of responsibilities However, this may be offset by the decreased reaction time

Concept C represents a dial-up situation where priorities are mainly determined on a first come first serve basis subject to astronaut intervention, of course It increases interaction by making the Space Station readily accessible by a dial-up procedure This concept maximizes interaction and minimizes the interaction loop complexity at the cost of minimum control Of course, the astronaut may always cut off communications with all experimenters and communicate through a central control point over a link designed for that purpose However, the main feature of this concept is the availability of the Space Station, which

enhances the principal investigators involvement It would also tend to bring the astronaut closer to the scientific planning stage, increase his knowledge of experiment operation, and aid his efficiency in running the experiment. The trade matrix developed for this study is shown in Figure 4 4-3.

From the matrix, it appears that single point control is only slightly more desirable than a completely random dial-up system, while forcing control to the Astronaut is the least desirable. If the cost factor were ignored, all three options would be comparable The single point control concept should be the least expensive to implement since only one (albiet frequency multiplexed) audio uplink between ground and the Space Station is required The dial up system would require either as many links as users or a complex switching center much like a central automatic switchboard Concept B would require a second link in addition to all the other equipment in order to maintain control while maintaining contact with the ground

EVALUATION CRITERIA	CENTRAL CONTROL POINT (A)			PAYLOAD CONTROL OF INTERACTION (B)			SHARED INTERACTION CONTROL (C)		
	Weight	Rating	Total	Weight	Rating	Total	Weight	Rating	Total
Ease of Control	10	10	100	10	6	60	10	1	10
Interaction Capability	10	4	40	10	6	60	10	10	100
Flexibility	3	5	15	3	7	21	3	10	30
Response Time	5	7	35	5	8	40	5	10	50
Ease of Expansion	10	5	50	10	5	50	10	5	50
Cost	10	10	100	10	6	60	10	8	80
TOTAL			340			291			320

Figure 4. 4-3. Central Control Vs Remote Control

None of the concepts discussed in Section 4 3 seem to have any significant advantages. However, because of communication technology problems with TDRS, remote locations for Principal Investigators seem to be too costly for consideration, at this time This study has been a preliminary investigation and the concepts previously discussed seem to be so closely rated that the recommendations made in this report should be subject to a thorough review prior to proceeding to the next design phase

The results derived in this study do not take into account any reductions as a result of on-board processing techniques. With increased capability in this area, interaction will become even more important in order to keep processing loads to acceptable levels Quick look evaluation of data finality by the Principal Experimenter will take on added importance in reducing the total data flow required to gather important scientific information

DATA REDUCTION 5

5.1 INTRODUCTION

5.1.1 SCOPE

The study was confined to the analysis of the twenty-six experiments selected by the "Experiment and Space Station Data Selection Study," Task I, which are experiments to be flown onboard the Initial Space Station (ISS)

5.1.2 STUDY APPROACH

The approach taken was to analyze the selected experiments to determine the sensors which would be used in the experiments Once the sensors were identified, their operational characteristics were investigated and the data error characteristics of each sensor or data source were defined Processing functions for each experiment were identified Then combining the processing functions with those functions required to correct the data error characteristics of the sensors and data sources, the processing system requirements were determined From these requirements, plus guidelines from NASA, and inputs from Data Dissemination studies alternative processing system configurations and cost estimates were made

5 2 IDENTIFICATION OF DATA INPUTS

The Data Reduction Study was started with a list of twenty-six experiments identified for the ISS period See Table 5 2-1 A list of the sensors or data sources was compiled according to the experiments in which they were used However, in studying the twenty-six experiments, it was discovered that many had sub-experiments, each using a different set of sensors, so that the number of experiments grew from twenty-six to seventy Considering it impractical to identify each sensor and determine its characteristics, a smaller but representative set of experiments was selected to estimate the processing system requirements for all of the original twenty-six experiments The experiments were considered from the higher level, i e , the sub-experiments were not considered separately, and all data rates and totals were examined at the level of the original twenty-six experiments

Table 5. 2-1 Initial 26 Experiments

A-4C	Small UV Survey Telescopes
CN-1B	Communications/Navigation
ES-1G	Minimum Payload
LA-1A	Life Sciences
MS-3A	Crystal Growth, Biological and Physical Processes
MS-3B	Crystal Growth from Vapors
MS-3C	Controlled Density Materials
MS-3D	Liquid and Glass Processing
MS-3E	Supercooling and Homogeneous Nucleation
P-1A	Atmospheric and Magnetospheric Science
P-1B	Cometary Physics
P-1C	Meteoroid Science
P-1D	Thick Material Meteoroid Penetration Experiment
P-1E	Small Astronomy Telescope

P-3C	Plastic/Nuclear Emulsions
P-4A	Airlock Boom Experiments
P-4B	Flame Chemistry and Laser Experiments
P-4C	Test Chamber Experiments
T-1A	Contamination Experimental Package
T-1B	Contamination Monitor Package
T-3A	Astronaut Maneuvering Unit
T-3B	Maneuvering Work Platform
T-4A	Long Duration Tests
T-4B	Medium Duration Tests
T-4C	Short Duration Tests
T-5A	Initial Flight Teleoperator

5.3 SELECTION OF REPRESENTATIVE SET OF EXPERIMENTS

The first step in the selection of a representative set of experiments was to compile tables consisting of the shuttle data and RF data with sub-categories of video, digital and film versus the list of twenty-six experiments (See Table 5 3-1 "Shuttle Digital and Video Tapes", Table 5 3-2 "Shuttle Film Data", Table 5 3-3 "R F Daily Data also Returned via Shuttle", and Table 5 3-4 "R F Daily Data not Returned via Shuttle). The difference between Table 5 3-3 and Table 5 3-4 is that the data listed in Table 5 3-3 does not have to be saved for archiving, the data is recorded on the spacecraft and returned via the shuttle each month The data listed in Table 5 3-4 is not recorded on the spacecraft so it must be recorded and processed for archiving as it is telemetered to the ground

With these tables completed, the experiments were selected so that the largest percent of the various types of data media would be represented and still keep the representative set of experiments to a reasonable number

The following is a list of the selected experiments and the main reasons for their selection

A-4C
The only astronomy experiment
2 5% of 35mm film
9 2% of RF video data

ES-1G
The only earth science experiment
100% of 240mm film
25% of 70mm film
85% of RF digital data
78% of shuttle digital data

LS-1A
Only life science experiment
75% of 70mm film
96% of 35mm film
16 8% of RF video data

MS-	This experiment is a combination of the worst cases for RF video data and RF digital data Therefore it represents all 13 MS experiments. 73% of RF video data 5% of RF digital data
P-1A	Consists of 17 sensors 75% of shuttle video data 3% of shuttle digital data
P-1E	UV similar to OAO experiments 4% of shuttle digital data 1% of 35mm film 2 4% of RF digital data
P-4C	75% of 16mm film 0 7% of shuttle digital data
T-1A	9% of shuttle video data 3 2% of 35mm film 0 2% of RF digital data
T-3A	8% of shuttle video data 7% of 16mm film
T-4A	< 1% of shuttle digital data 4% of RF digital data

After the selection of these representative experiments, the sub-experiments were no longer taken into consideration, i e , the sub-experiment characteristics were lumped into the characteristics of the prime (original twenty-six) experiments

Table 5 3-5 contains a list of the representative experiments and their percent of the total data per month per media

5.4 DATA FLOW DEVELOPMENT

Following the selection of the representative set of experiments, the next step was to identify the processing functions required for each of the experiments The processing functions to be performed were dependent upon the type of data (video, digital), the data media (tape, film), and the method of data return to the ground (shuttle or telemetry) for each experiment

To estimate the requirements of a digital data reduction ground system with any degree of accuracy it is necessary to determine the processing required for each of the data sources or sensors such as the UV Spectrometer, and to know the detailed operations of those data sources The telemetry or digital data tape format will also impact the amount of processing time required to separate the data and format it for displays or output

Table 5. 3-1. Shuttle Data

	Experiment	Bits Recorded Per Month	Percent of Monthly Total
Digital Tapes	CN-1B	6,760 0 × 10^7	
	ES-1G	297,000 0 × 10^7	78%
	P-1A	10,320 0 × 10^7	3%
	P-1B	21 6 × 10^7	
	P-1C	1 × 10^7	
	P-1D	52 0 × 10^3	
	P-1E	13,520 0 × 10^7	4%
	P-4A	4,212 0 × 10^7	
	P-4B	43,200 0 × 10^7	11%
	P-4C	2,730 0 × 10^7	0 7%
	T-1A	1,526 0 × 10^7	0 4%
	T-1B	19 2 × 10^7	
	T-3A	16 2 × 10^7	< 1%
	T-3B	60 5 × 10^7	
	T-4A	224 7 × 10^7	< 1%
	T-4B	135 2 × 10^7	
	T-4C	2,240 0 × 10^7	
	T-5A	2 1 × 10^7	
	Total	382,387 6 × 10^7	
Video Tapes	T-1A	23 9 HR @ 10 MHz (2-4 MHz)	(9%)
	T-3B	21 0 HR @ 3 MHz	(8%)
	P-1A	192 0 HR @ 0 33 MHz	(75%)
	T-3A	9 0 HR @ 3 MHz	
	T-3A	9 0 HR @ 4 MHz	(8%)
	Total	254 9 HR	

Table 5. 3-2. Shuttle Data

	Film in Frames			
Experiments	16 MM	35MM	70MM	224MM X 350MM
LS-1A	-	100,000 (94%)	88,630 (75%)	-
T-4B	-	520	-	-
ES-1G	-	-	28,800 (25%)	7,200 (100%)
T-4C	76,000	-	-	-
P-4B	(9%) 150,000	50 (< 1%)	-	-
T-1A	-	3,440 (3 2%)	-	-
T-3A	(7%) 129,000	-	-	-
T-3B	(7%) 126,000	-	-	-
A-4C	-	2,496 (2 3%)	-	-
P-1C	-	5	-	-
P-1E	-	780 (1%)	-	-
P-4C	(75%) 1,248,000	-	-	-
Totals	1,730,000	107,291	117,430	7,200
Meters	27,680	3,755	8,220	2,520

Table 5. 3-3. RF Daily Data - Returned Via Shuttle

Experiment	Video	Digital	R T Process	Days/Month
P-1E	-	52×10^7	100%	26
P-4A	-	$16\ 2 \times 10^7$	100%	26
P-4B	-	220×10^7	100%	20
T-1A	0 1 HR @ 10 MHz	$5\ 87 \times 10^7$	100%	26
T-1B	-	48×10^7	100%	4
T-3A	-	54×10^7	100%	3
T-4A	-	$8\ 64 \times 10^7$	1-7 day	26
T-4B	-	$2\ 6 \times 10^7$	1-7 day	26
T-4C	-	$28\ 0 \times 10^7$	1-7 day	4
ES-1G	-	$2{,}200 \times 10^7$	1% RT 1 orbit 1-7 day	22
Average RF/Day/Month	0 1 HR @ 10 MHz	$2{,}120\ 5 \times 10^7$		
Monthly Total	2 6 HR @ 10 MHz	$55{,}133\ 6 \times 10^7$		

Table 5. 3-4. RF Daily Data - Not Returned Via Shuttle

	Total Hrs/Month	Video/Day	Digital/Day	Days/Month
LS-1A	52	2 HR @ 4 MHz	7 X 10^7	26
MS-3A 1	7	7 HR @ 3 3 MHz	28 8 X 10^7	1
3A 2	48	16 HR @ 3 3 MHz	18 0 X 10^7	3
3A 3	56	14 HR @ 3 3 MHz	4 32 X 10^7	4
3A 4	16	4 HR @ 3 3 MHz	21 6 X 10^7	4
3A 5	16	4 HR @ 3 3 MHz	43 2 X 10^7	4
MS-3B 1	12	6 HR @ 3 3 MHz	21 6 X 10^7	2
3B 2	6	3 HR @ 3 3 MHz	10 8 X 10^7	2
MS-3C 1	12	6 HR @ 3 3 MHz	0 216 X 10^7	2
3C 2	16	8 HR @ 3 3 MHz	0 18 X 10^7	2
3C 3	10	5 HR @ 3 3 MHz	216 0 X 10^7	2
MS-3D.1	4	4 HR @ 3 3 MHz	0 144 X 10^7	1
3D 2	6	6 HR @ 3 3 MHz	216 0 X 10^7	1
MS-3E 1	16	8 HR @ 3.3 MHz	73 8 X 10^7	2
A-4C	28 6	8 HR @ 3 3 MHz	4 3 X 10^7	26

$\frac{305\ 6}{624}$ = 49% available time   1514 4 X 10^7 month

Average Daily Totals   11 7 HR @ 3 3 MHz 58 247 X 10^7

All above information must be recorded on ground – It is not sent down by Shuttle

Hrs/Month (624) = Days/Month (26) X Hrs/Day (24)

The number of data sources on the ISS was not only too numerous to research and analyze thoroughly, but the sensors themselves were insufficiently defined to do a thorough analysis As a result, an attempt was made to group all data sources by experiment and to determine the processing required for each experiment

The prime concern in identifying the processing functions was to take the data in the form it was received, separate it by experiment, calibrate it, format it and put it on a medium (tape or film) so that it would be in a form suitable for the user and/or archives

5.4.1 DATA FLOWS, SIX DISCIPLINES

The following pages contain the data flows required to process all the data for the experiments considered except Earth Resources In some cases there are up to five data flows per experiment, each flow representing the processing required for a separate type of data, e g , RF video, RF digital, shuttle video, shuttle digital, and 35mm film These flows are shown in Figures 5 4-1 through 5.4-9

Table 5. 3-5. Representative Experiments Versus Data Media

Exp.	Shuttle Data: Digital	Video	Samples	16mm	35mm	70mm	240mm	Percent of Total Monthly R F.: Video Note 1	Digital Note 2	Digital Rate	Comments
A-4C	-	-	-	-	2.5%	-	-	9.2%	0.1%	500 bps	
ES-1G	78%	-	-	-	-	25%	100%	-	85 4%	.5Mbps	
LS-1A	-	-	-	-	96%	75%	-	16.8%	0.3%	12Kbps	
MS-See Note 3	-	-	Samples	<1%	-	-	-	73%	5%	10^4 bps	
P-1A	3%	75%	Samples	-	-	-	-	-	-	-	17 Sensors
P-1E	4%	-	-	-	1%	-	-	-	2 4%	12Kbps	UV Spectrometer
P-4C	0.7%	-	-	75%	-	-	-	-	-	-	
T-1A	0.4%	9%	-	0.6%	-	-	-	<0.1%	0.2%	2Kbps	
T-3A	<0.1%	8%	-	7%	-	-	-	-	0.1%	500 bps	
T-4A	<0.1%	-	-	-	-	-	-	-	.4%	1Kbps	

Note 1 Total of 308.6 hrs per month for all R.F. Video Data (2.6 hr + 305.6 hr)

Note 2 Total of 56648. x 10^7 bits per month for all R.F. Digital Data (55134 + 1514)

Note 3 MS represents 13 MS Experiments; Video is total for all 13, Data Rate is worse case

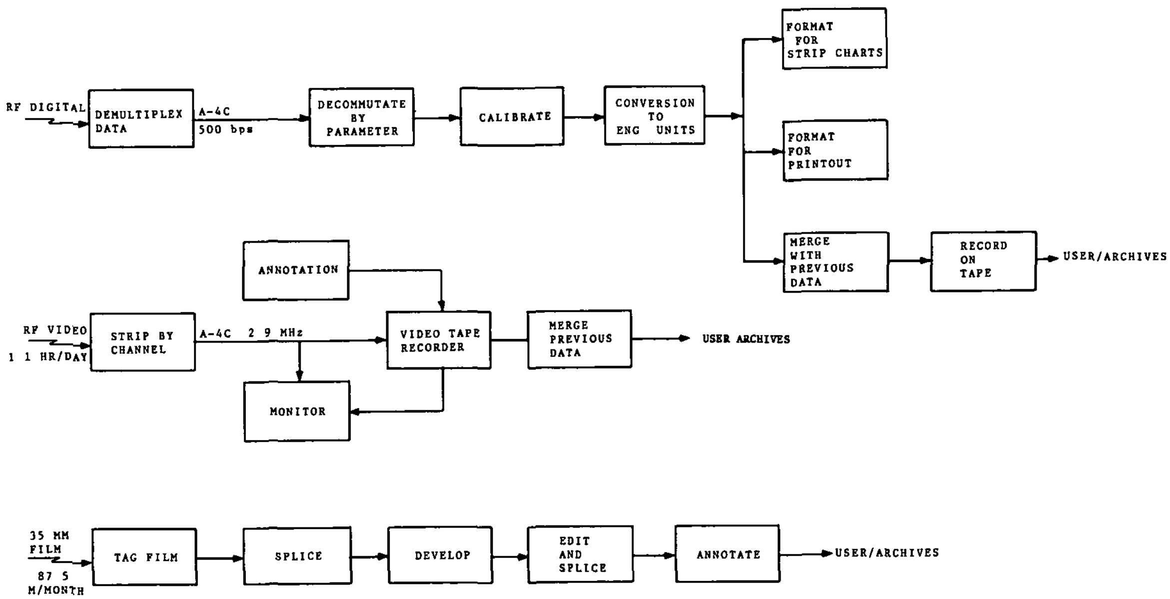


Figure 5. 4-1. A-4C Data Flow

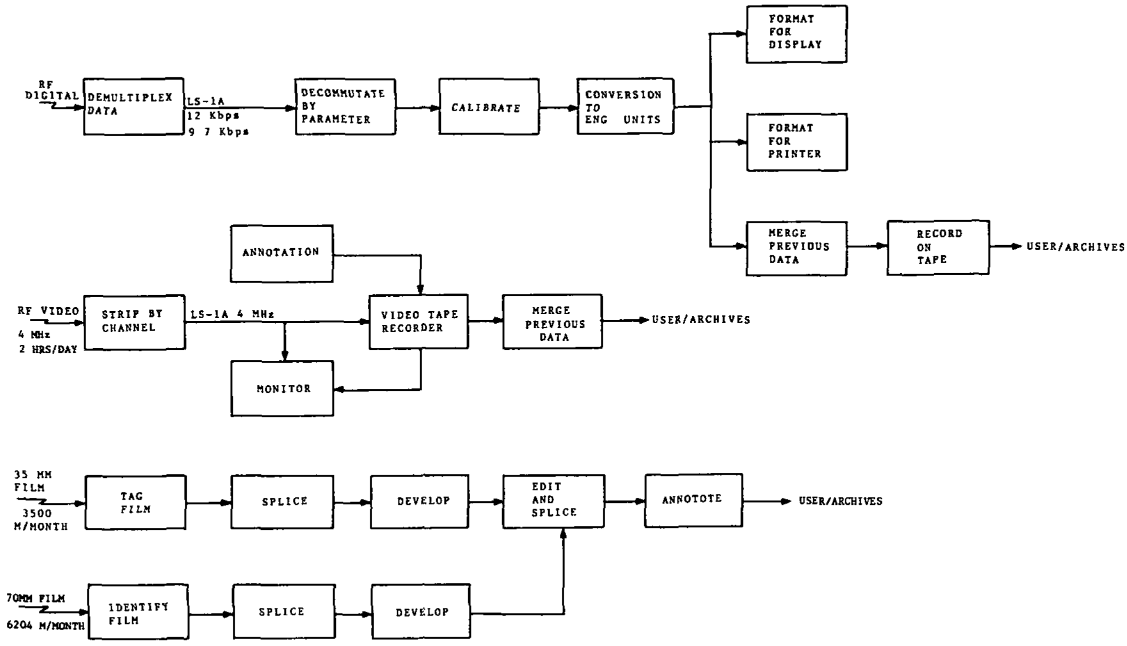


Figure 5.4-2. LS-1A Data Flow

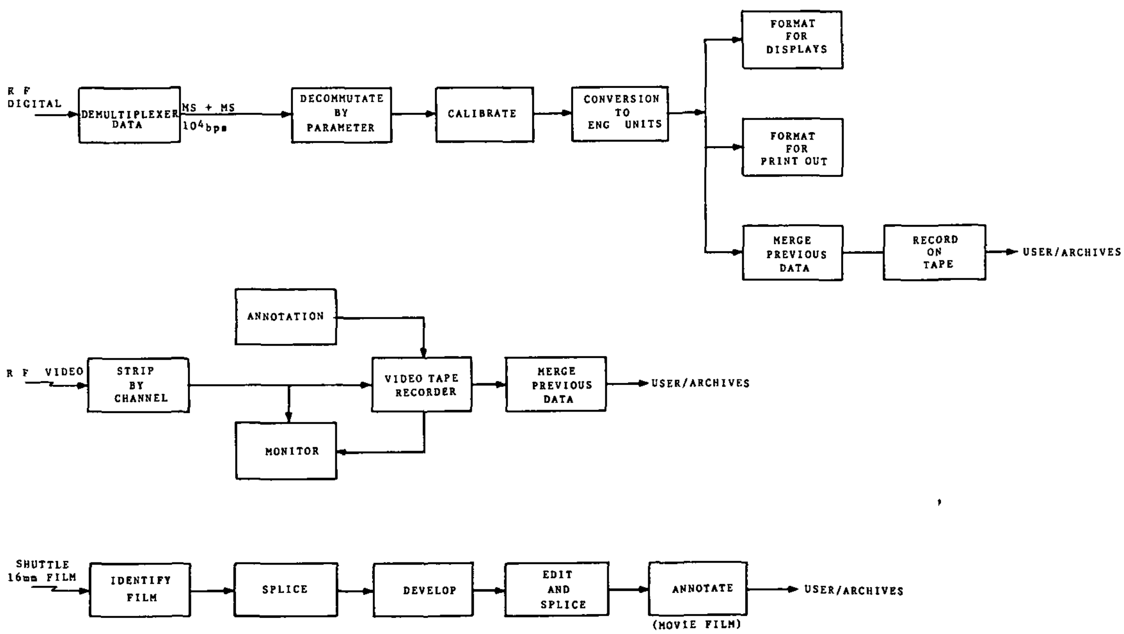


Figure 5. 4-3. MS and MS Data Flow

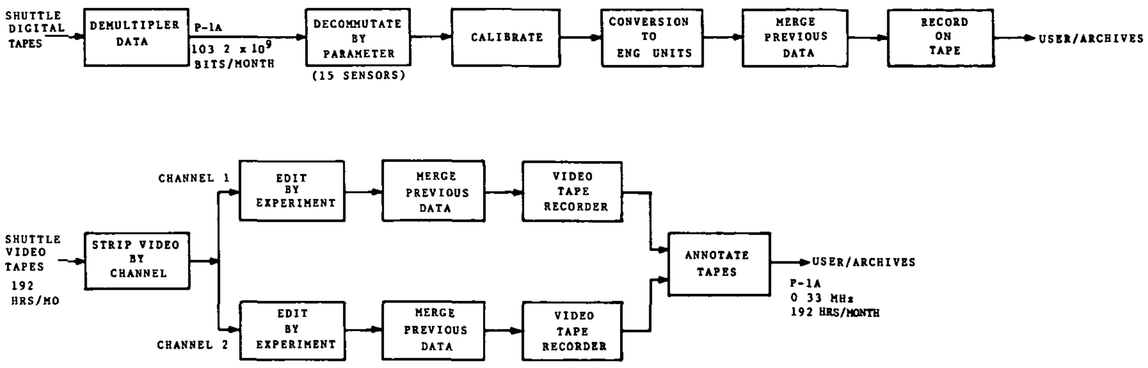


Figure 5. 4-4. P-1A Data Flow

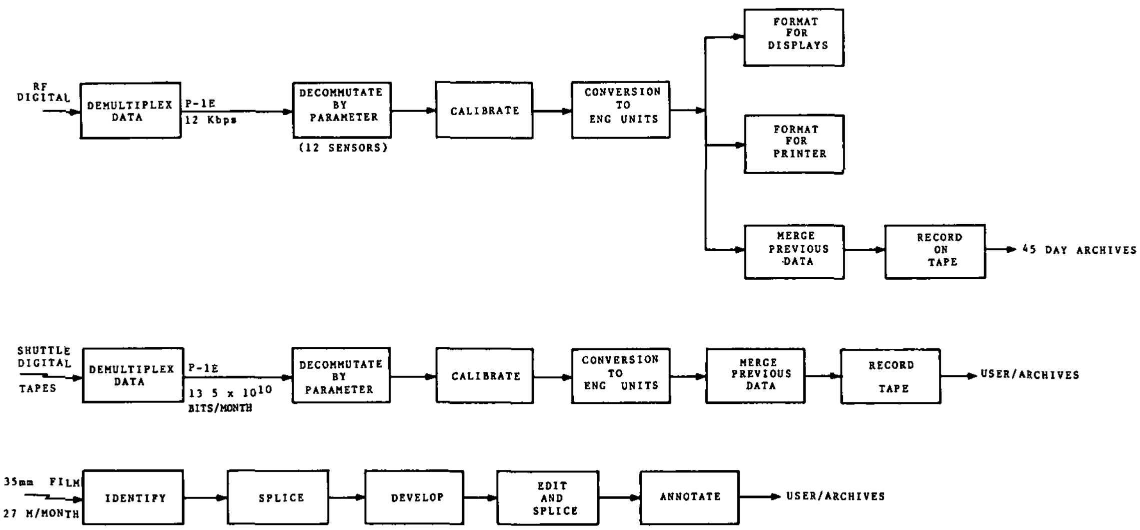


Figure 5. 4-5. P-1E Data Flow

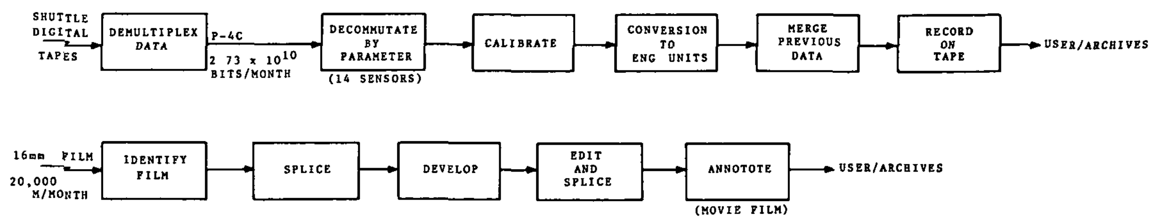


Figure 5. 4-6. P-4C Data Flow

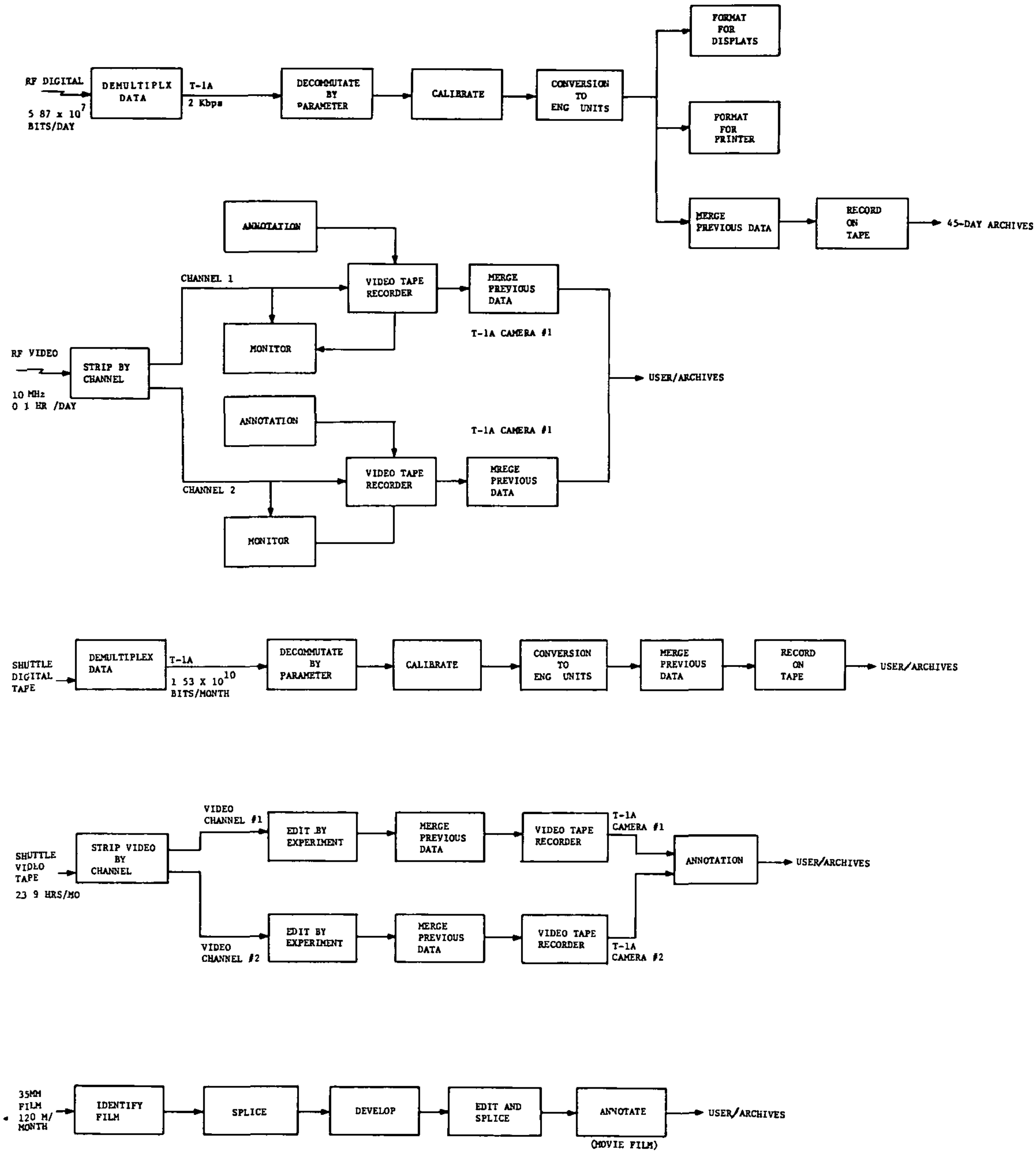


Figure 5. 4-7. T-1A Data Flow

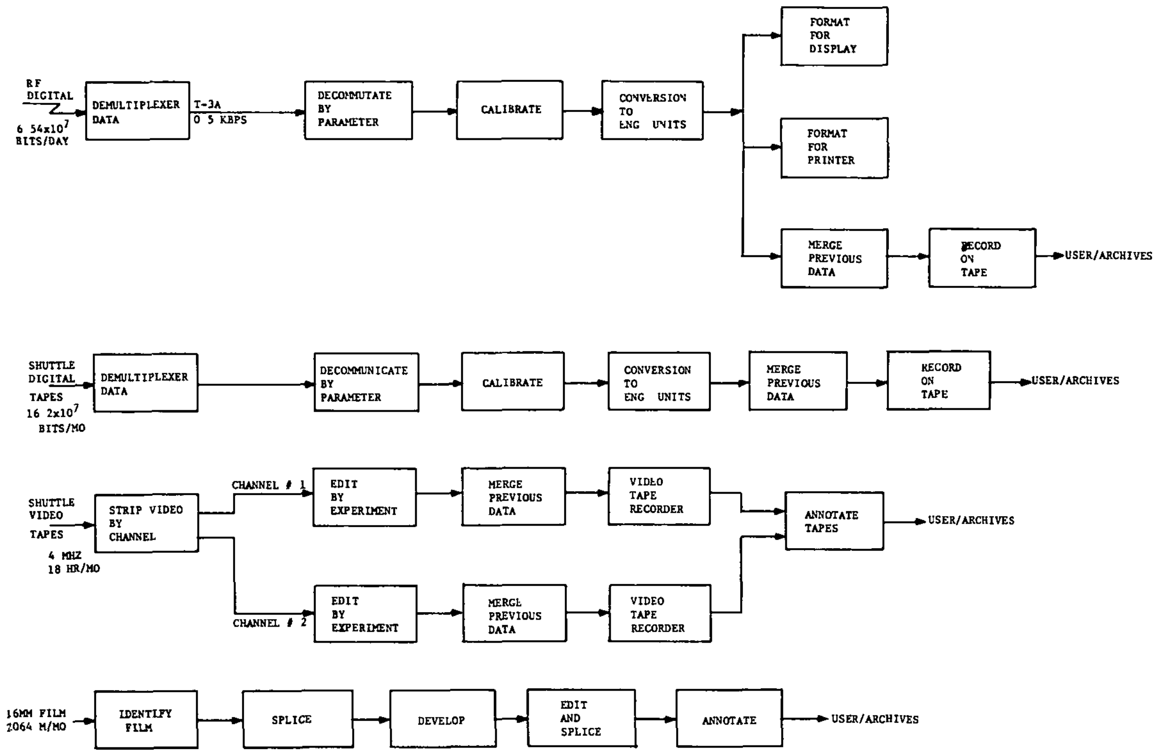


Figure 5. 4-8. T-3A Data Flow

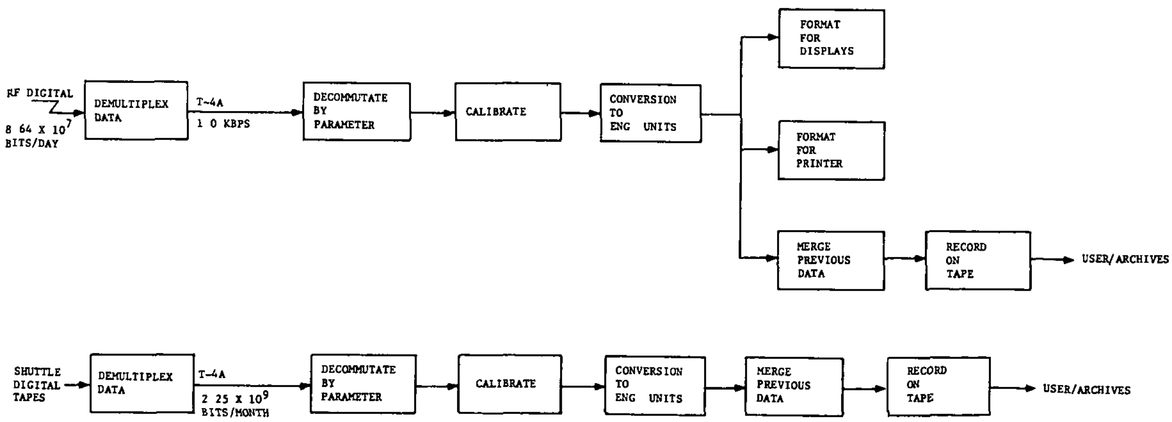


Figure 5. 4-9. T-4A Data Flow

5.4.2 PROCESSING FUNCTIONS, EARTH RESOURCES

A majority of the Shuttle returned data is generated by the six sensors described in this section Whereas there were great similarities in the processing steps in the other six disciplines, Earth Resources is unique in processing steps, data load, and application For these reasons, it is treated separately Processing for each of the six sensors is described below

5.4.2.1 Stellar Camera

The 70 mm film from the four stellar cameras is developed Corresponding frames from each of the cameras are grouped and given an identification tag The metric camera attitude corresponding to each group of stellar camera frames is determined by one of the following two alternate processes

- The stellar camera frames undergo a geometric correction based on preflight (and, possibly, in-flight) optical calibration The geometric correction is accomplished in an electro-optical processor which produces corrected film This film is developed in a normal fashion The corrected frames are placed in an optical comparator where they are tilted and rotated until they can be made to match corresponding photographs of the celestial sphere The rotations necessary to achieve such a match are transmitted to the real-time processing computer where they are used to compute the attitude of the metric camera

- The stellar camera frames are scanned in a film scanner and transformed into lists of star locations and intensities which are transmitted to the shuttle processing computer The star locations are corrected on the basis of the optical calibration data The corrected star locations are put through rotational transformations until they match stored star tables The metric camera attitude is computed from the required rotations

When the original stellar camera film emerges from the electro-optical processor or film scanner it is sent to archival storage

5.4.2.2 Metric Camera

The 240mm film from the metric camera is developed, the frames are separated into logical groups (e g , all the frames from a given orbital pass might constitute a group) and an identification leader is attached to each group Annotation information for each frame (time, frame number, orbit, sun angle, co-ordinates of frame corners and center, etc) is generated in the shuttle processing computer

The metric camera frames are corrected geometrically and photometrically by one of the two following alternate processes

- An electro-optical processor is used to apply the geometric and photometric corrections, which are determined on the basis of preflight and in-flight calibration information, attitude data as derived from the stellar camera frames, and space station ephemeris data The output of the processor is latent film Annotation is applied to each frame by equipment which is either an integral part of or an attachment to the electro-optical processor

- The film is run through a film scanner where it is scanned and digitized The digital data is fed to the shuttle processing computer where it is corrected geometrically and photometrically Annotation information is merged with the image data stream to form corrected, annotated images which are recorded on digital tape The tapes are placed on a film recorder which records the processed images on 240 mm film

The latent film resulting from the correction process is developed, and copies are made The master images are archived, and the copies are distributed to users

5.4.2.3 Multispectral Television (MTV)

The MTV data is returned by the shuttle on high density digital tape, multiplexed with a variety of other digital information The digital tapes are played on a demultiplexer which splits out the MTV information and records it on a separate tape

The MTV information is in the form of 8-bit (256 distinct levels) samples Since photographic films are limited to approximately 100 distinct values and present optical and electro-optical processors require that the data be recorded on film at some stage of the process, neither optical nor electro-optical processing is suitable for the MTV data Some form of digital processing must be used

The MTV data tapes are read into the shuttle processing computer Annotation information for each frame is generated, and geometric and intensity corrections based on preflight and in-flight calibration data are applied to the frames For each frame, redundant spectral values are averaged to produce a single set of data values spanning the spectral range of the sensor The "compacted" spectral data and annotation information for each frame are recorded on digital tapes These tapes are copied and distributed to interested users

5.4.2.4 Multispectral Scanner

The Multispectral Scanner, because of the high volume of data which it generates, imposes the greatest data processing load on the ground system Ultra high density (UHD) tapes returned by the shuttle are played on a demultiplexer where the multispectral scanner data is split out Information for each of the five channels of the multispectral scanner is recorded on a separate tape (i e , five data tapes are generated simultaneously) Due to the large volume of data, these tapes must also be UHD tapes

Since the multispectral scanner data is in the form of 9-bit samples (512 distinct levels), digital processing is the only alternative, for the reasons given in the discussion of the MTV above

It is assumed that, in order to be useful to investigators, the data must be converted from the conical scan format in which it is generated to a rectangular raster format of equivalent resolution. (This is the approach planned by NASA-Houston for the scanner which will be flown on Skylab as part of the EREP) Two methods for "straightening" the scans have been considered

The first of these is to perform the scan straightening function in the shuttle processing computer as part of a general geometric correction Since a single straight line will map across more than 1150 conical scan lines and each of the conical scans contains more than

4800 9-bit samples, this approach requires that the shuttle processing computer have at least 12 megabytes of memory Although no present-day computers have this much memory, there appear to be no major technical reasons which such a memory capacity cannot be achieved if one is willing to bear the cost.

An alternative approach is to design and build a special-purpose "scan straightener" whose purpose would be to convert the conical scan data to a rectangular format It appears that a series of shift registers of appropriate length could accomplish this Such a device would use UHD tape for input and output In this latter approach it would still be necessary to transmit the straightened scan data to the shuttle processing computer in order to remove distortions caused by such effects as scanner attitude variations However, since these distortions are small, no more than one megabyte of computer memory is required to handle them

In the shuttle processing computer the data (either conical or straightened) is corrected for geometric and radiometric distortions Annotation information is generated and merged with the data stream The straightened, corrected, and annotated data is recorded on UHD tape "Framing" of the data, including overlap, is accomplished by proper control of the output tapes

The multispectral scanner output data tapes are played into a film recorder which records the data on 240mm film Although the film will not provide the full resolution of the original data, it is believed that such a presentation format is required to enable users to select areas of interest from the data tapes The film is developed, and copies are made These copies, along with copies of the data tapes, are distributed to users and the archives

5.4.2.5 Microwave Scanner (MWS)

Data from the MWS is stripped from the shuttle digital data tapes in the demultiplexer and is recorded on separate tapes These tapes are read into the shuttle processing computer where geometric and radiometric corrections are applied Annotation information is generated and merged with the data stream

The corrected and annotated data is recorded on computer compatible tapes (CCT) "Framing," if desired, is accomplished by proper control of the recording process The output tapes are copied anddistributed to users

5.4.2.6 Scatterometer/Radiometer (SR)

The SR data is stripped from the shuttle digital data tapes in the demultiplexer and is recorded on separate tapes which are then read into the shuttle processing computer The outputs of the scatterometer and radiometer are corrected for geometric and radiometric errors, and the altimeter outputs are calibrated Appropriate annotation information is generated Scatterometer, radiometer, and altimeter data values are merged with annotation on computer compatible tapes which are copied and distributed to users

5.4.3 DATA FLOW, EARTH RESOURCES

This section shows the data flows required to process all data from the Earth Resources data sources described in the previous section, 5 4 2, as returned by the Shuttle once per 30 days See Figure 5 4-10

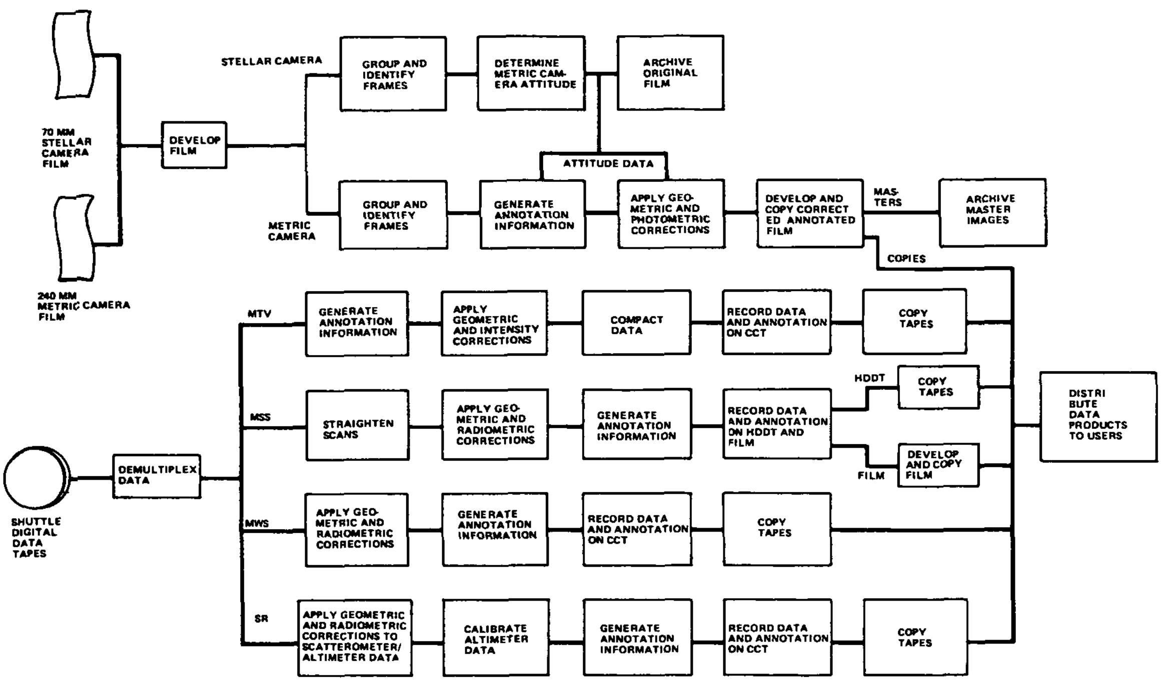


Figure 5. 4-10. Earth Resources Data Flow

5.5 PROCESSING SYSTEM

Figure 5 5-1 shows the total data reduction system in block diagram form The two methods of receiving data from the space station are via telemetry and the shuttle Telemetry provides real time inputs for the video system for closed circuit television type information which is to be displayed on monitors and recorded on video tape Telemetry also provides real time digital data which goes to the digital system and is processed for quick-look data analysis

The shuttle returns video tapes, digital tapes, and various types of film The video tapes go to the video system where they are separated by experiment and recorded on video tapes for shipment to the users and archives The digital tapes are processed by the digital system where the data is separated by experiment and recorded on digital tape for shipment to the user and archives The film is processed by the film system where it is developed, edited and printed where necessary for shipment to the user and archives

5.5.1 REAL TIME PROCESSING SYSTEM

The real time processing system handles all of the experimental RF data as it is telemetered from the spacecraft to the ground. Some of the data which is telemetered to the ground for real time monitoring is also recorded on tape in the Space Station and returned via the shuttle This type of data is processed in real time to drive status board displays, strip charts, TV monitors, and provide hard copy print-out for on-the-ground monitoring of the experiments This data will also be recorded on tape and held for approximately 45 days or until its duplicate, which was recorded on tape in the Space Station, is received via the shuttle and verified for completeness

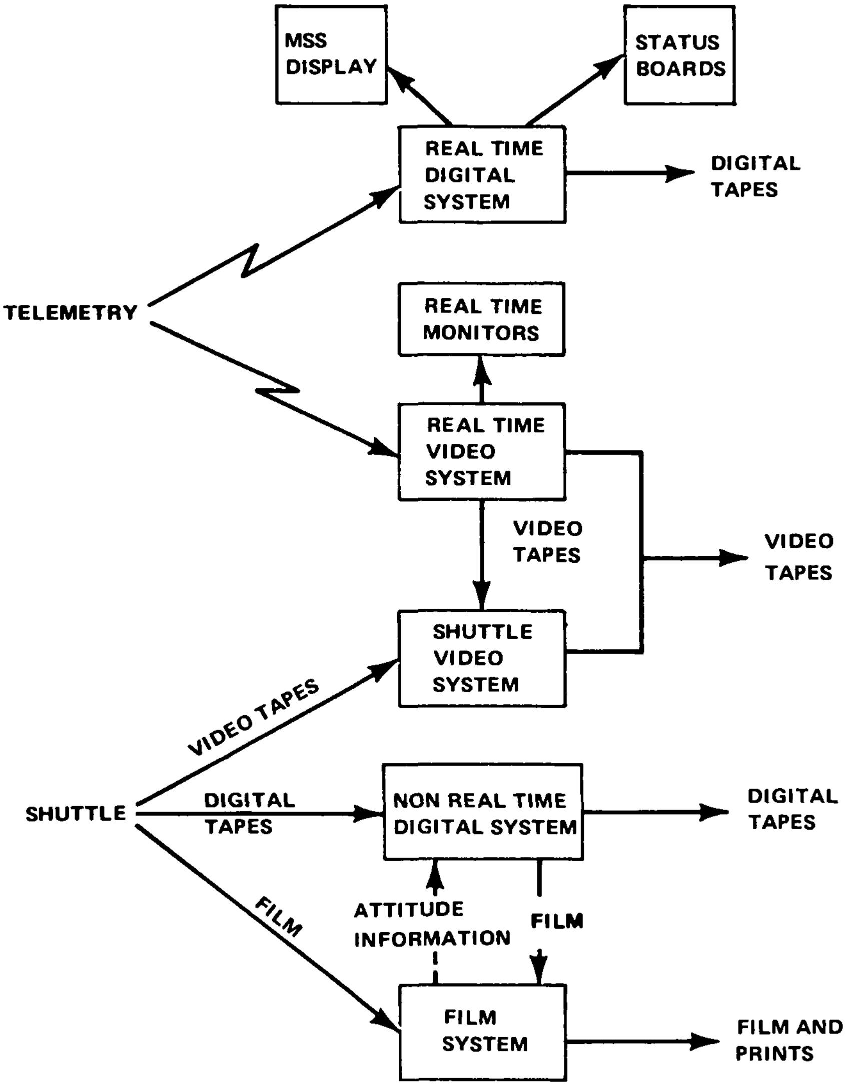


Figure 5. 5-1. Overall Data Reduction System

The rest of the experimental RF data is not recorded in the Space Station as it is telemetered and therefore, after is has been processed on the ground for the real time monitoring function, it will be recorded on tape to be sent to the user and/or the archives

The real time processing system consists of two independent systems The Real Time Video System, and The Real Time Digital Processing System

5.5.1.1 Real Time Video System

The Real Time Video System, Figure 5 5-2, will receive the RF video signal, strip it from its carrier, split it into its two video channels, display the video on TV monitors, and record each channel on 5 08 cm video tape

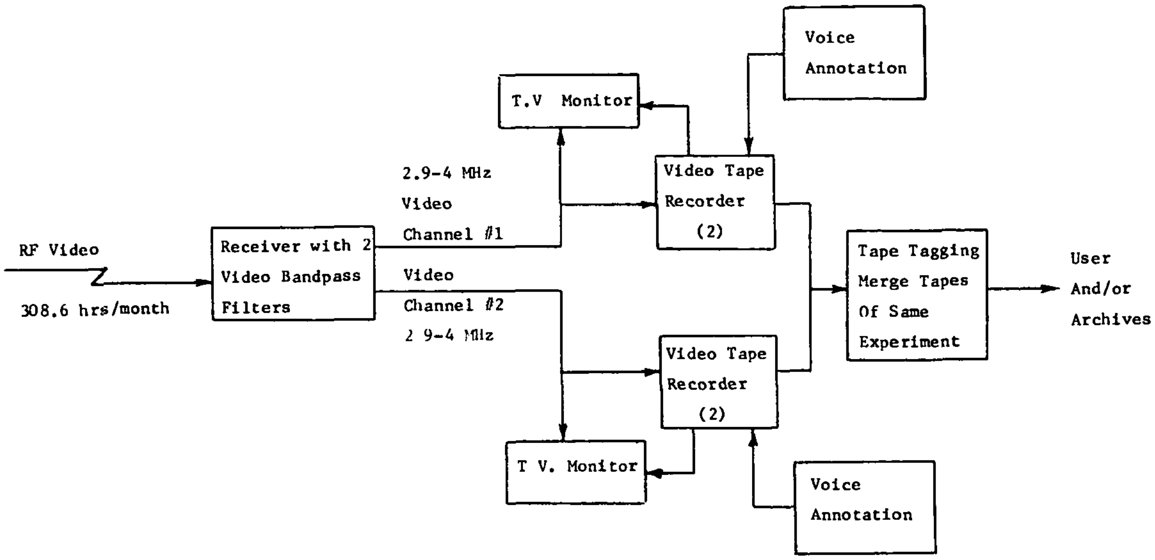


Figure 5. 5-2. Real Time Video System

The 5 08 cm video tape will have a video track, an audio track, a utility track, and a timing track The video and audio tracks will be used to record the video signal and the associated voice comments of the astronauts as telemetered to the ground The utility track will be used for voice annotation by the experimenters on the ground and/or will be used for control purposes The controlling functions could include stopping the tape at the end of one experiment and prior to the start of the next experiment This would be very helpful when trying to merge several recordings from the same experiment onto a single reel for shipment to the user or archives

In most instances an experiment will use only one video channel However, there are several experiments, such as The Contaminant Dispersal Measurement Experiment, which uses two TV cameras simultaneously It is therefore necessary to have two complete video channels, duplicate tape recorders and duplicate TV monitors

Another requirement considered was how much RF video data had to be handled on a daily basis In looking at the various experiments and their RF video requirements the maximum daily load was found to be 19 2 hours per day, assuming that it is reasonable to have only one MS experiment on at any given time This information is shown in Table 5 5-1

Table 5. 5-1. Maximum Daily Load of RF Video

LS-1A	2 0 hr
A-4C	1 1 hr
T-1A	0 1 hr
MS-3A-2	16 0 hr
	19 2 hr per day

The audio which accompanies the video may be connected to a speaker near or in the monitor if the monitor is in a room set aside for the experimenters where everyone in the room is interested in what is happening or the audio could be connected to phone jacks if the monitor is in a large operations room where a speaker would interfere with the operations personnel.

It would seem reasonable to have several video tape recorders per video channel so that there would be no loss of data while reels are being changed or while the recorders are being serviced Another benefit of several video tape recorders would be that of editing or merging all of the data from one experiment onto one reel If the video data being telemetered is switched from one experiment to another the tape recorders could be switched at the same time preventing two experiments from recording on the same reel Then when the first experiment starts sending video again, the tape recorders can be switched back

During the time when there is no video being telemetered or when it is using only one channel, the other channel can be used to monitor past experiments by putting the tape recorder in playback mode While the tape recorder is in the playback mode the video would be viewed on the monitor and the ground based experimenters can use this time to edit the video tapes and to voice annotate if desired by using the utility track of the video tape It is also possible to voice annotate the video tape as it is being recorded from telemetry by using the utility track, that is, if the ground personnel have information or comments they wish to record It is also quite feasible that the audio track could be used to record the astronaut's voice and the utility track used to record any ground comments while the experiment is in progress

Typical video tape recorders of the RCA or Ampex variety with 5 08 cm tape capability and suitable for codes would cost approximately 100K each Most video tape recorders of this quality have built in monitors

5.5.1.2 Real Time Digital Processing System

The Real Time Digital Processing System, Figure 5 5-3, contains a computer, two high density computer compatible tape units, four low density, 620 bits/cm (1600 bpi) computer compatible tape units, a printer, status boards, card equipment, 800MB (Mega Byte) DASF (Direct Access Storage File) and a CRT type display for MSS data The system will receive the telemetered experiments digital data and strip the earth sciences data from the main data stream for display on the CRT tape monitor The rest of the data will go to a computer to be decommutated, calibrated, converted to engineering units, and formatted for output to status displays, printer hard copy, and computer compatible tapes which will be sent to the users and archives

The telemetered experiment digital data will be received at a rate of 600 Kbps This will enter the demultiplexing hardware which will strip out the ES-1G real-time digital data from the rest of the digital data and direct it to a CRT display which has a scan similar to the scan of the sensor The remaining data will go through the real time channel of the computer where it will be decommutated by experiment and sensor At this point the data will be calibrated and changed to engineering units using stored tables containing the conversion and calibration values for each parameter The values in these tables will be updated to include the results from any inflight calibration data When the data is written on tape it will be done so that there will be only one experiment's data on any one reel of tape Prior to

outputting the data on tape, it will be buffered in the computer for some nominal period of time so that when the data is written on tape it will be grouped according to the sensor from whence it came and each group will contain all the data gathered for those sensors for that nominal period of time

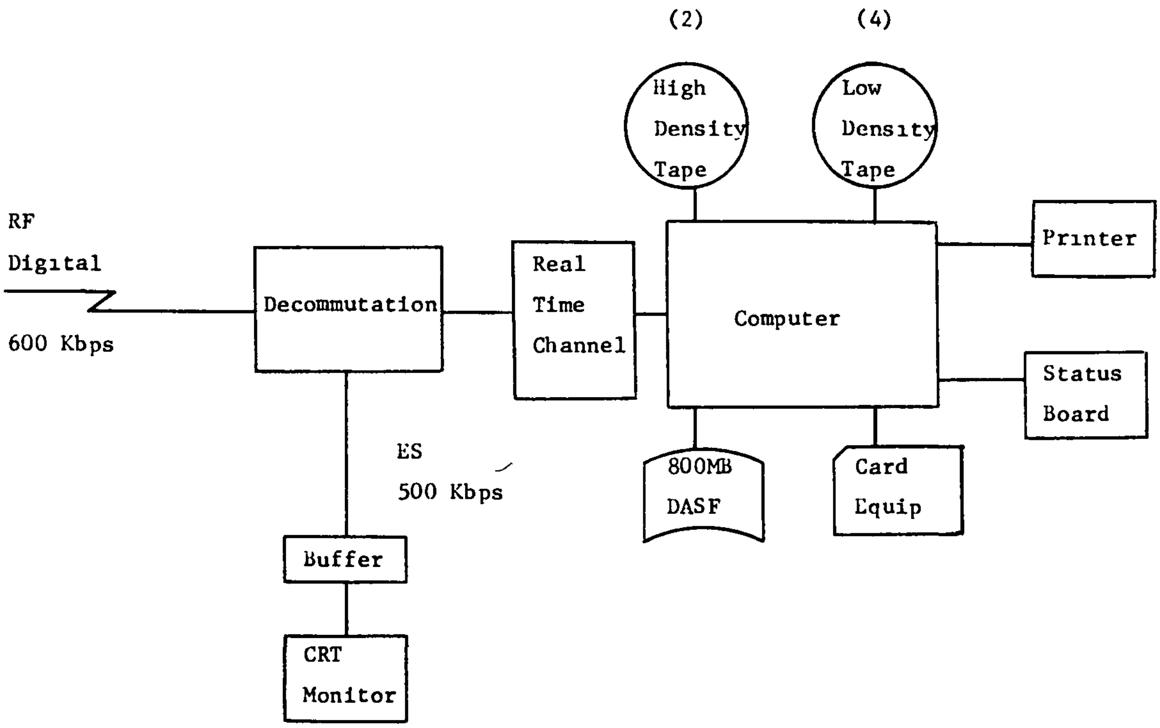


Figure 5. 5-3. Real Time Digital Processing System

The data will also be formatted in preparation for the hard-copy output from the printer when requested from an experiment ground controller Other outputs from the computer will be the data to drive the experiment consoles, status displays, and strip charts

Derivation of the computer size to handle the digital data returning by RF requires identifying each of the steps in the data flow and assigning an appropriate number of computer instructions to each step The cumulative computer instructions per second can then be calculated using the data rates that were derived in Section 2 Examination of the data flows in Section 5.4.1 reveals that the steps are similar in all cases of data returned by RF A typical data flow is therefore shown in Figure 5 5-4.

The assignments of instructions per byte are typical numbers of instructions required for each of the steps identified in the flow diagrams These are shown in Figure 5.5-5

Figure 5 5-6 shows the data return rate derived for the ISS time period The maximum rate, from this figure is approximately 600 Kilo bits per second

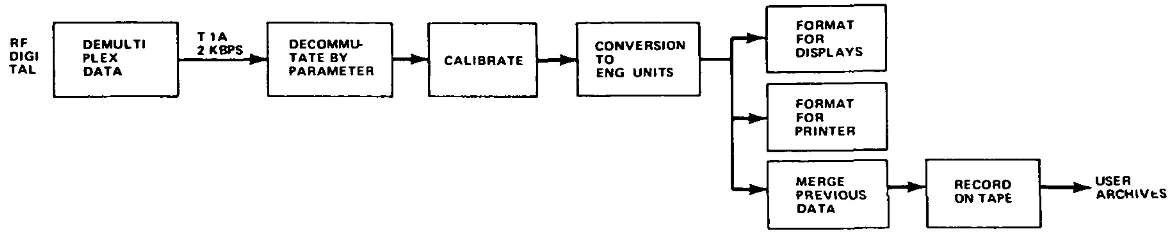


Figure 5. 5-4. Typical Data Flow

PROCESSOR FUNCTION	RF DATA (ALL) INSTRUCTIONS/BYTE
• Demultiplex Data	5
• Decommutate and Verify by Parameter	13
• Calibrate	3
• Convert Data	5
• Assemble Message	6
• Merge and Correlate	
• Record and/or Display	8
TOTAL	40

Figure 5. 5-5. Instruction Assignments

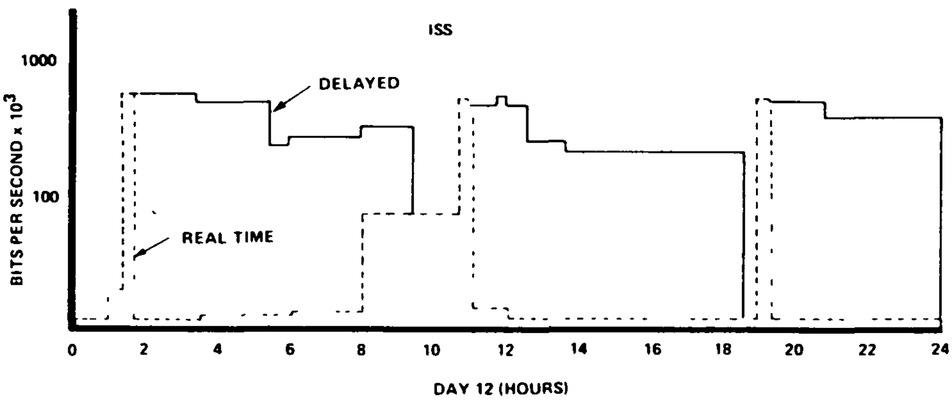


Figure 5. 5-6. RF Digital Data Return

Calculation of computer size from these figures is as follows

6 X 10^5	bit per second
37 5 X 10^4	bytes per second (8 bits/byte)
1 5 X 10^3	messages per second (50 bytes/message)
15	blocks per second (100 messages/block)

Incorporating computer instructions for overhead functions with the instruction requirements of Figure 5 5-5 requires the following calculations

40	instructions per byte
X 50	bytes per message
2 X 10^3	instructions per message
+ 1 X 10^3	instructions per message I/O overhead for reading input and generating displays
+ 0 1 X 10^3	instructions per message for blocking tape output
3 1 X 10^3	instructions per message
X 100	messages per tape block
3 1 X 10^5	instructions per tape data block
+ 500	instructions for tape I/O overhead
3 1 X 10^5	instructions per tape data block
X 15	tape data blocks per second
4 5 X 10^6	instructions per second

From these calculations the computer required to handle the RF digital data returned in real-time and near real-time must have the operating rate of 4.5 instructions per second

5.5.2 SHUTTLE-RETURN PROCESSING SYSTEM

The Shuttle-return processing system handles the data returned via shuttle once each 30 days The processing system is derived and sized here in terms of a single facility, although in implementation the system may be distributed Distribution of the system is developed in Section 9, System Definition

5.5.2.1 Shuttle-Return Video System

The Shuttle Video System, Figure 5 5-7, will take the video tapes returned from the space station via the shuttle, split the two video channels, separate the data on each channel by experiment, merge the data from the same experiment, record the merged data on 5 08 cm video tape and tag the reels for shipment to the user and/or archives

The Shuttle-Video System uses the same type of video tape recorders as are used in the Real Time Video System The tapes will have a video track, an audio track, a utility track, and a timing track. Once again the utility track can be used for voice annotation and/or control, same as in the Real Time Video System

The main difference between the Real Time Video and the Shuttle Video System is what happens to the signal prior to being recorded In the Real Time System there is a receiver to accept the video telemetry signal and strip it from its carrier In the Shuttle System the input is a two-channel video tape which must be read and the video channels separated The Shuttle Video System could have a monitor connected to the tape recorders to assist in editing and merging the data from the experiments

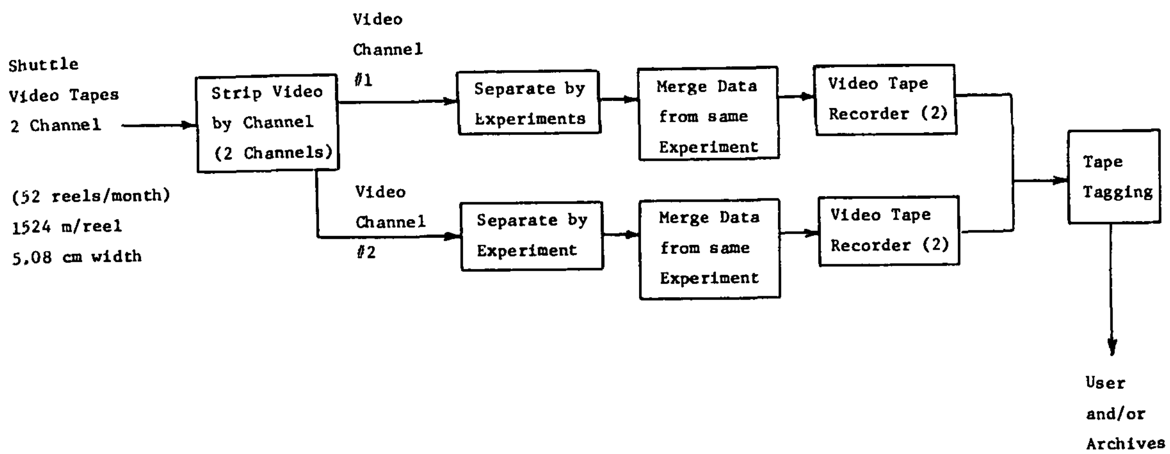


Figure 5. 5-7. Shuttle Video System

5.5.2.2 Shuttle-Return Digital System

The non-real time digital system, Figure 5 5-8, consists of a computer, thirteen high density computer compatible tape units, eleven low density 620 bits/cm, (1600 bpi) computer compatible tape units, 100MB direct access disk, card equipment, printer, film scanner, film recorder, one special-purpose piece of equipment to straighten the scan lines of the MSS, and a demultiplexer

The high-density digital tapes which are returned via the shuttle are mounted on the demultiplexer unit which separates the data by experiments, checking the identification tags, and puts the data on high density computer compatible tapes for those experiments with large amounts of data, and on low-density computer compatible tapes for the other experiments Each reel of tape contains the data from only one experiment The MSS high-density tapes may optionally be put on the special-purpose Scan Straightening unit and the data run through

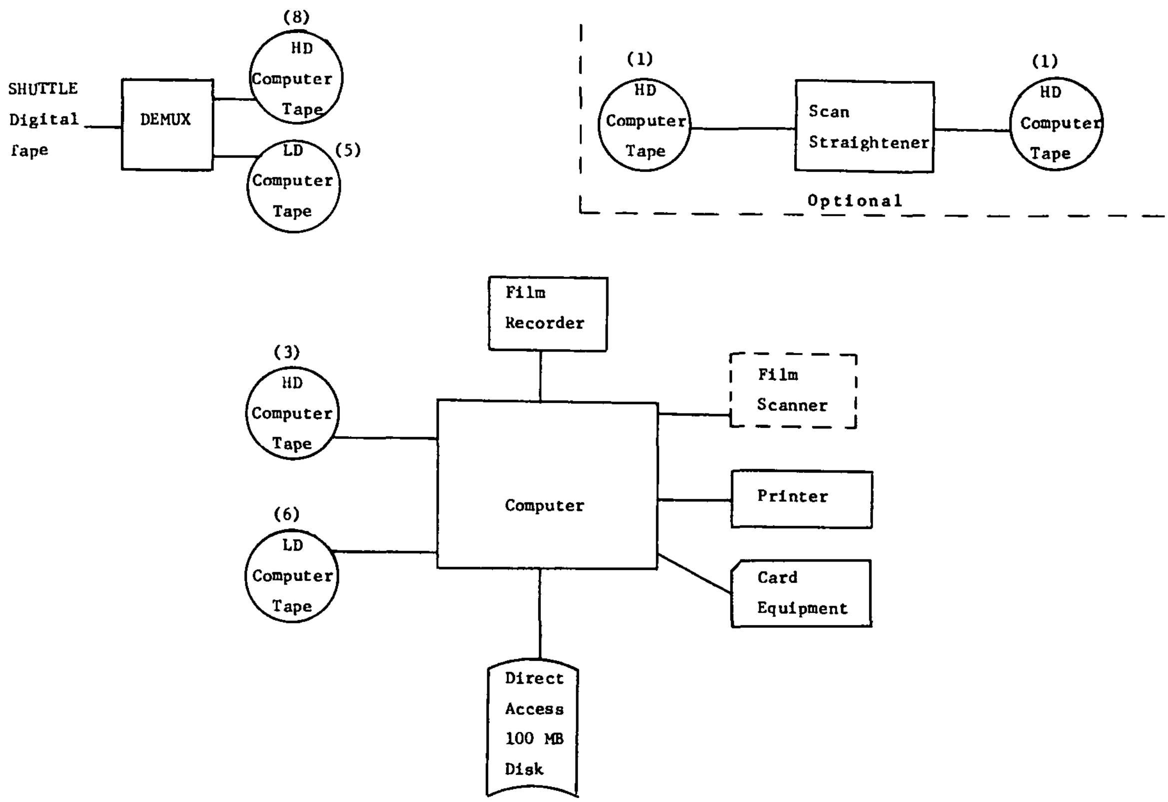


Figure 5. 5-8. Non Real Time Digital System

the unit onto another high-density computer-compatible tape After having been processed by the scan straightener unit the data will now contain straight scan lines which can be processed by the computer for image errors

After the data for each experiment has been put on computer-compatible tape, it is now ready to run through the computer for processing and be eventually written on tape which will be sent to the user and archives

Calculation of the computer sizing is done in two parts, since the handling of Earth Resources data is somewhat more complex than for the other six disciplines Using a calculation similar to that in Section 5 5 1 2, Real Time Digital Processing System instructions per second for the six disciplines are derived as follows

$7\ 6 \times 10^{11}$	bits/month
$9\ 5 \times 10^{10}$	bytes/month
$1\ 9 \times 10^{9}$	messages/month
$1\ 9 \times 10^{7}$	data blocks/month
$7\ 33 \times 10^{8}$	data blocks/sec

The figure of 7 33 data blocks per second ıs computed on the basıs of processıng the shuttle return data 24 hours per day, and wıth the lımıtatıon that processıng must be completed wıthın 30 days, sınce another delıvery wıll be made by the shuttle at the end of that perıod Sınce processıng 24 hours per day permıts no down tıme, (consıderıng a computer) two alternatıve schedules are calculated, two eıght hour shıfts, and a twenty hour operatıng day yıeldıng data handlıng requırements of 11 2 and 8 8 data blocks per second, respectıvely

The number of computer ınstructıons per byte requıred to handle thıs shuttle return data ıs shown ın fıgure 5 5-9

PROCESSOR FUNCTION	RECORDED DATA (EXCLUDING ER) INSTRUCTIONS/BYTE
• Demultıplex Data	10
• Decommutate and Verıfy by Parameter	25
• Calibrate	10
• Convert Data	15
• Assemble Message	10
• Merge and Correlate	25
• Record and/or Dısplay	3
TOTAL	98

Fıgure 5 5-9. Instructıon Assıgnments

Completıng the calculatıons as ın Sectıon 5 5.1.2, and usıng the fıgure of 98 ınstructıons per byte shows a total of 5 01 $\times$ 10^5 ınstructıons per data block Multıplyıng by 11 2 and 8 8 data blocks per second yıelds the followıng computer sızes for handlıng shuttle return, non-Earth Resources data

5 6 $\times$ 10^6 ınstructıons per second, two shıfts per day

4 4 $\times$ 10^6 ınstructıons per second, 20 hours per day

Calculatıon of computer sıze for handlıng shuttle returned Earth Resources data ıs done on a sensor basıs, because the number of bıts per sample varıes from sensor to sensor

Multıspectral Televısıon (MTV) calculatıons are as follows

	2 Shifts	20 Hours
8 bit samples/month	$9\ 4 \times 10^{9}$	$9\ 4 \times 10^{9}$
seconds/month	$-\ 1\ 73 \times 10^{6}$	$-\ 2\ 16 \times 10^{6}$
samples/second	$5\ 43 \times 10^{3}$	$4\ 35 \times 10^{3}$
samples/scan	$-\ 1\ 55 \times 10^{4}$	$-\ 1\ 55 \times 10^{4}$
scans/second	$3\ 50 \times 10^{-1}$	$2\ 81 \times 10^{-1}$

- Assume 118 instructions per sample
- Assume 15,500 samples per scan
- 1,000 instructions per scan, overhead
- Yields (42 shifts) 64×10^{6} instructions per second
- Yields (20 hours/day) 52×10^{6} instructions per second

Multispectral Scanner calculations

- Yield (2 shifts) $25\ 7 \times 10^{6}$ instructions per second
- Yield (20 hours/day) $21\ 1 \times 10^{6}$ instructions per second

Earth Resources Computational Requirements are summarized in figure 5 5-10 Note that the Microwave Scanner and the Scatterometer/Radiometer requirements do not affect, substantially, the total requirements

5.5.2.3 Film System

The Film System, Figure 5 5-11 will receive various sizes of film, e g , 16mm, 35mm, 70mm and 240mm, and various types of film, e g , black and white, color, infrared and special purpose. The system must take this film, develop it, edit, merge, splice, and in some cases, print it

The first function performed by the system as the film is received is to punch the leader of each reel, cassette, and magazine with an identification code which will be used to sort the film according to the experiment it is associated with after it has gone through the developing phase After the film is tagged or punched, all film of the same size and type is spliced together and fed through the developing tanks as one long, continuous strip As it emerges from the developing tanks and dried, it is wound on large reels which will be taken to the editing, sorting and splicing area It is here that all film for a particular experiment is grouped together If the film is 16mm, it is spliced together to form 16mm movie film The 35mm film for certain experiments, such as those in Life Sciences, is spliced together for Time and Motion Study movie film The 70mm film from the stellar camera used in the Earth Sciences experiments and is used to determine the attitude of the metric camera which

INSTRUMENT	PROCESSING FUNCTIONS	INSTRUCTIONS PER SECOND	
		2 Shifts	20 Hrs /Day
Multispectral Television	• Demultiplex • Generate Annotation and Annotate • Correct for Internal and External • Compact Data • Record Data • Copy Tapes	64 X 10^6	.52 X 10^6
Multispectral Scanner	• Demultiplex • Straighten Scans • Correct for Internal and External Errors • Generate Annotation and Annotate • Record Data and Write Film	25.7 X 10^6	21.1 X 10^6
Microwave Scanner	• Demultiplex • Correct Data • Generate Annotation and Annotate • Record and Copy	.045 X 10^6	
Scatterometer/ Radiometer	• Demultiplex • Correct Data • Calibrate Altimeter • Record and Annotate	.01 X 10^6	
	TOTAL COMPUTATIONAL REQUIREMENT	26 4 X 10^6	21 6 X 10^6

Figure 5. 5-10. Earth Resources Computational Requirements

uses the 240mm film Therefore the 70mm film from the stellar cameras must be time correlated with the 240mm film from the metric camera

There is a possibility that the same developing tank could be used for all film sizes and types After each type of film is developed the tanks could be drained, cleaned or flushed and refilled with the proper chemicals for the next type of film

5.6 SYSTEM COSTS

Table 5 6-1 contains the engineering estimates of the costs for the various equipment units required for the data reduction ground system Several alternate hardware configurations can be made using these units Table 5 6-2 is a list of four configurations which would be used. There are other alternatives to these configurations discussed in Section 5 7

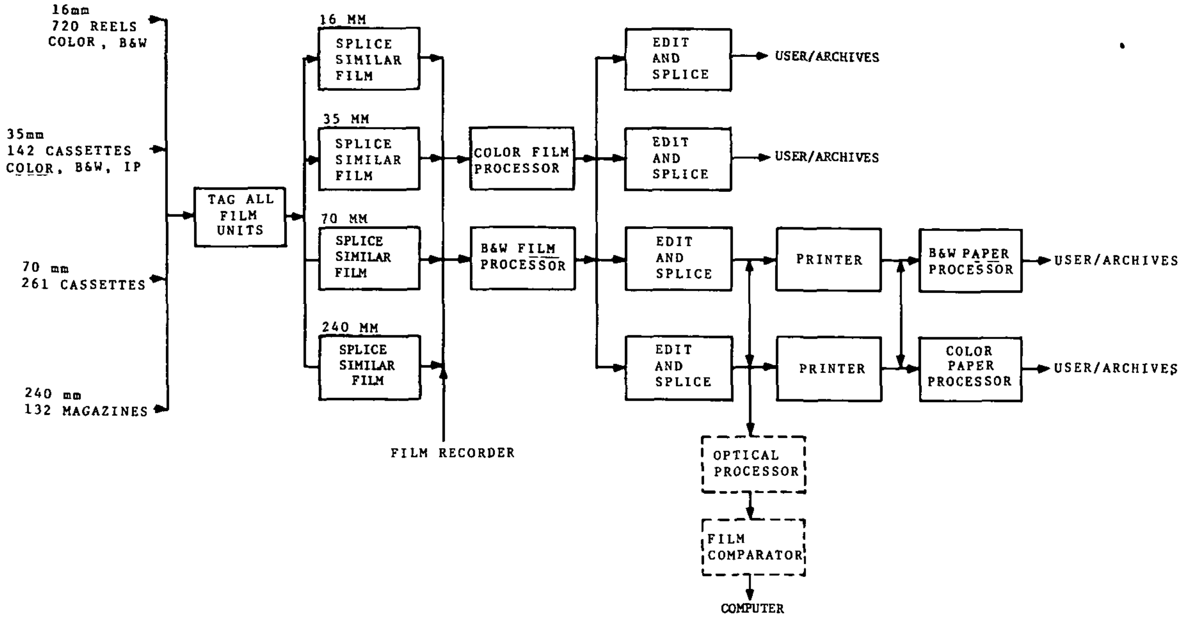


Figure 5. 5-11. Film System Configuration

Table 5. 6-1 Equipment Costs

Equipment	Cost
Demultiplexer	$2 0M
Decommutator	1 0M
HD Tapes & Controllers (16 @ $0 2M)	3 2M
Real Time MSS Display	0 2M
240mm Film Recorder	0.5M
Video Tape Recorders (8 @ $0 1M)	0 8M
Film Processing System	
B&W Film Processor @ $30K	
Color Film Processor @ $60K	
B&W Paper Processor @ $15K	
Color Paper Processor @ $40K	
Printer (2 @ $15K) $30K	0 175M
Film Scanner	0.5M
Optical Processor	0 5M
Film Comparator	0.05M
MSS Scan Straightner	4.5M

Table 5. 6-2 Configurations

Configuration

1 Computer, 12MB Memory
Computer, 1MB Memory
Optical Processor
Film Comparator
Demultiplexer
Decommutator
HD Tapes & Controllers
Real Time MSS Display
240mm Film Recorder
Video Tape Recorders
Film Processing System

2 Same as No 1 but replace Optical Processor and Film Comparator with Film Scanner

Configuration No 1
Optical Processor
Film Comparator
Film Scanner

3 Same as No 1 but replace Computer and 12MB Memory with Computer, 1MB Memory, and MSS Scan Straightener

Configuration No 1
Computer, 12MB Memory
Computer, 1MB Memory
MSS Scan Straightner

4 Same as No. 3 but replace Optical Processor and Film Comparator with Film Scanner

Configuration No 3
Optical Processor
Film Comparator
Film Scanner

5.7 ALTERNATIVES

In the data reduction system configurations which were presented in previous sections, there are alternatives which can be considered

In the video system there is the possibility of sharing the video tape recorders between the RF video system and the shuttle video system Most experiments require only one video channel so that the other channel could be used to copy, edit, or annotate video tapes

In the film processing system it is possible to use the color film processor and color paper processor to process the black and white film and paper However, if this is done, extreme care must be taken to prevent the contamination of chemicals. When changing from the black and white to the color processing or vice versa, the tanks must be thoroughly cleaned prior to the addition of new chemicals

The alternatives for the shuttle digital system have already been discussed in previous sections

DATA ARCHIVAL 6

6.1 INTRODUCTION

6.1.1 SCOPE

This section documents the work which was accomplished in the Data Archival study The scope of the study was confined to the experiment data loads generated by the Initial Space Station (ISS) In this respect, the data loads used were based upon the experiments selections described in Section 2 and the outputs generated by data reduction described in Section 5 Even though some consideration was given to the requirements of the Growth Space Station (GSS), the study's quantitative results were based only on ISS

6.1.2 STUDY APPROACH

The approach taken in the study was first to define the functional requirements that the data archival system for ISS must satisfy These included the classification of the data types and their loads by discipline, the definition of the indexing and cataloging requirements, the development of retention criteria (i e , preparation of a rationale for data purging) for the data to be stored in the archives, and estimation of the response times needed to handle requests from a diversity of users The archiving responsibility was considered at a point in the data flow at which all inputs from the Space Station have already been processed by a Data Reduction Facility, i e , after they have been edited and grouped or split by experiment.

Having defined the functional requirements, the approach was then to make a trade-off analysis of the advantages and disadvantages of centralization or decentralization of archival storage and its division between NASA and user data centers Prior to selecting an archiving system configuration, an evaluation was made of the state of the art in mass storage technologies during the time period of the Space Station program and an analysis was made of the existing and planned archiving system concepts and associated software Candidate configurations were then selected and the most likely alternatives were evaluated on an equipment cost basis The results and conclusions of this analysis become recommendations to the System Definition Task described in Section 9

6.2 FUNCTIONAL REQUIREMENTS

The requirements that follow are designed to meet the mission objectives of the Space Station In order to fulfill its mission, the Space Station Archival System must process and store a wide variety of data including digital and analog magnetic tape, film and hard copy It must verify all inputs to the system, detect errors and perform quality control In addition it must provide for an efficient exchange of data from a large and diversified group of experimenters to the worldwide user community

A key to the success of determining functional requirements for a data archival system is an accurate assessment of demands of the system Since the experiments provide experimental data for a wide range of scientific and engineering disciplines, the potential users of this information in the academic and industrial environment are many and widely dispersed, geographically Therefore it has been necessary to consider a sample representation of the user population to project the needs and desires to the total community. Specific user requirements were in the process of collection during the performance of this subtask, so some assumptions and generalizations were necessarily applied in performance of this subtask General user requirements were obtained from studying existing NASA facilities such as the National Space Science Data Center (NSSDC) and existing documentation of AAP and ERTS

archival studies, as well as from personnel working on the user requirements task The results are presented in terms of ranges of values in place of specific values in some cases

6.2.1 ARCHIVAL FUNCTIONS

The fundamental concept of the archival storage and retrieval system is two fold As an archive it must have the characteristics of a permanent repository This implies measures must be taken to ensure the acquisition and maintenance of complete source data records, including the duplication and periodic exercising of data, with strict quality and environmental control A major objective of the storage and retrieval system, is that it be "user oriented" that is, it must provide the right data to the right person at the right time

In order to characterize the overall requirements for the archive storage and retrieval complex, it is convenient to consider five basic functions of such a system They are acquisition, surrogation, announcement of availability of data, data management and dissemination

The data acquisition function and the characteristics of the anticipated experiments data were studied in Tasks 1-3 of this study, and estimates of volumes were made Surrogation is the process of substituting for an item something that will represent it or stand in its place For archival purposes, this includes coding, indexing, cataloging and abstracting In the data portion of the archival system, a surrogate may be a keyword, an accession number, a title, etc Announcement of the availability of acquired data items to the field of intended users can be performed automatically by matching an incoming items index against a file of user interest terms Descriptive information is then sent to the user when a close match occurs The data management function refers to all data handling accomplished within the data archive system Dissemination includes the physical or electrical transfer of data to the user Dissemination is discussed in the following requirements section

6.2.2 ARCHIVAL REQUIREMENTS

The general requirements that follow are designed to fulfill the overall objectives of the space station

a The system must handle large amount and varieties of data (discussed in the next section) The data to be archived will consist primarily of digital and analog magnetic tapes, various sizes of film and indices and textual abstracts of samples Other data the archival system must handle includes digital information files for special processing, indices, abstracts, and hard copy

b The system must provide rapid and simple communication with the user The user would like to describe his problem in a language and discipline that is part of his every day activities Specific requirements for man-machine communications include the following

- Program routines should be problem oriented as well as technique oriented
- The language should be oriented toward common English language and contain a minimum amount of special coding and abbreviations
- The programs should contain automatic error checking routines to assist the user

- Provisions must be made for a dialogue with the user so that standard operating procedures, etc , may be displayed to the user The system thus provides a capability for training the user

c The system must provide tools for assisting personnel to maintain the data base Although some minor corrections of the data base will occur, the prime maintenance items are data refreshing (if a magnetic tape system is used for storage), and purging Refreshing simply involves reading a magnetic tape and/or rewinding it on another spool to reduce errors

Purging is required to keep the volume of data within bounds and to eliminate outdated data However, other methods are available to make storage space available These methods fall into two categories, reducing data without losing information content and reducing data by reducing its information content Methods of accomplishing the above follow

Reducing data without losing content

- Eliminating certain data through statistical sampling techniques
- Data compaction techniques

Reducing data by reducing its information content by

- Breaking out event data from background data
- Preserving only special data for historical purposes
- Compressing data into analyzed forms

d The system must include a phased growth potential The next section indicates a large amount of growth in digital data is anticipated from the initial to growth space stations Additional growth may occur due to increased user queries, etc Therefore, the capability for planned expansion must be provided in the initial system design by a modular type growth from ISS to GSS to accommodate increased data quantities without requiring major redesign of the system or of programs

e The system must provide management and other support information files A number of information files will be required to support the archival system These will include, but not necessarily be limited to, the following principal files

- Thesaurus
- Locator
- Bibliographic
- Abstract
- Data Management

A thesaurus file represents a list of all terms used to index A locator file relates the terms to the material or data in which they were used A bibliographic file describes the material

or data (e g , date, experiment, title, etc.) An abstract file contains brief summaries of experiments, data, etc Data management files provide various statistical records (e g , number of queries and retrievals, throughput times, purging statistics and predictions, etc) All of these files may be accessed or modified by composing Boolean expressed queries

f The system must provide a means to train users Specific requirements for the amount and level of training will depend on the educational and technical level of the individual user At a minimum, the training should address system orientation and user operating procedures A certain amount of this training can be presented through the archival systems user/input displays and controls through interactive (conversational) query techniques Brief guides to instruct in system operating procedures, experiment data holdings, new data lists, etc , should be available for local viewing or remote viewing In addition, formal training should be provided for all system operators as well as management and appropriate user groups

6.2.3 ARCHIVAL DATA SUMMARY

The Space Station archive system must deal with many different forms of data in order to house a wide variety of experiment categories and satisfy the demands of a equally diversified field of users

Between the time an experiment is conducted on board the Space Station and the time the Principle Investigator publishes his final results the experiment data will undergo an assortment of data handling and processing operations. The raw analog and digital data receive via telemetry (i e , RF data) will be recorded at the sites and sent physically in analog form or converted to digital form and electrically transmitted to the preprocessing site. The majority of this RF data will be duplicated in the raw analog and digital tapes brought back at thirty day intervals by the shuttle (also sent to the preprocessing site for preprocessing) The RF data mentioned above will be stored for 45 days or until the shuttle data has been verified to be good It will then be purged from the archive

The preprocessing is performed before the tapes are sent to the user and includes A to D conversion, decommutation, quality control checking, stripping of experiment data, error corrections, etc These tapes are referred to as "preprocessed" tapes in this report Other data returned by the shuttle will include physical samples, film, and hard copy data logs Copies of preprocessed tapes, samples, films and hard-copy logs will be sent to the experimenter for data reduction and/or analysis The final experimenter-reduced and/or analyzed data will be returned to the archives based on predetermined criteria for retention

6.2.3.1 Archival Data Categories

Categories of data available for archival include

a Raw digital data - received electrically from remote site or physically (magnetic tapes) from shuttle or remote site.

b. Raw analog data - received physically (magnetic tapes) from remote site or shuttle

c Preprocessed digital data - above data after being preprocessed

d Film - from shuttle

e Samples - from shuttle

f Hard copy - from shuttle (e.g. logs, etc)

g Experimenter processed digital data.

h. Experimenter processed film

i. Experimenter processed hard copy

6.2.3.2 Archival Data Loads

Figure 6 2-1 shows archival data estimates (by discipline) of digital, video, film and samples for the ISS Figure 6 2-2, Archival Storage Time shows estimates of data requiring storage from one month of Space Station data, as well as archival time requirements Raw digital and analog RF data are stored on line for 45 days or until the shuttle data has been determined to be good RF data not duplicated in the shuttle data is treated the same as shuttle data Preprocessed digital data and film will be stored for 2-3 years or until the experimenter has processed the data and it is received at the archive Two to three years is the nominal time that NASA usually requires for contractor users to finish reducing and analyzing the data Samples need not be stored in the archive, however, index and/ or abstract information such as the sample characteristics will be stored and maintained up to four years unless an experimenter can justify longer archival Non-repeatable experiment data (e g , astronomical data) will be stored permanently

6.2.4 ARCHIVE DESIGN CRITERIA

The criteria which follow result from and are based on studies of existing NASA facilities as well as from personnel working on the user requirements tasks They represent criteria which must be considered in the design of the archive system

a Store all RF data between shuttles

All RF data must be stored between the 30 day shuttle runs. In order to determine if the data is good the data must be stored in minimum of 15 additional days or until the shuttle data has been verified

b Archive all experiment processed data for the duration shown in Figure 6 2-2

c Number of users is expected to be in the range from 100 to 2000

d Frequency of data base access is estimated to be about 20% of the total user population, accessing 5% of the total data base a day.

e Retrieval response times required are expected to range from 1 second to 48 hours It is projected that one percent of the queries will require a 1 second response and up to 75% will require a 48 hour retrieval time. The faster response queries will be addressed to the information files Figure 6 2-3 shows expected response time ranges for documents, tapes, film and information queries.

	Data Type	Physics	Astronomy	MS&MS	Technology	Com/Nav	Life Science	Earth Resources	Total
RF	Raw Digital	$30\ 8\text{x}10^{10}$B	$11\ 2\text{x}10^{8}$B	$13\text{x}10^{9}$B	$42\ 3\text{x}10^{9}$B	$67\ 6\text{x}10^{9}$B	$18\ 2\text{x}10^{8}$B	$29\ 7\text{x}10^{11}$B	$3403\ 84\text{x}10^{9}$
	Raw Video	192 hrs @ 33 MHz	---	225 hrs @ 3 3 MHz	24 hrs @ 10 MHz 39 hrs @ 3 3 MHz	---	---	---	118 hrs @ 10MHz
Preprocessed	Pre-Processed Digital	$30\ 8\text{x}10^{10}$B	$11\ 2\text{x}10^{8}$B	$13\text{x}10^{9}$B	$43\ 3\text{x}10^{9}$B	$67\ 6\text{x}10^{9}$B	$18\ 2\text{x}10^{8}$B	$29\ 7\text{x}10^{11}$B	$3403\ 84\text{x}10^{9}$
	Film	1,398,835 F	2,496 F	---	861,400 F	---	601,000 F	36,000 F	2,899,731
	Video	192 hrs @ 33 MHz		225 hrs @ 3 3 MHz	24 hrs @ 10 MHz				118 hrs @ 10 MHz
	Hard Copy	10 P	26 P	20P	39 hrs @ 3 3 MHz	5 P	26 P	26 P	123 P
	Samples	---	---	---	---	---	---	---	TBD
	Support Info	---	---	---	---	---	---	---	TBD
Experimenter Processed	Processed Digital	$30\ 8\text{x}10^{10}$B	$11\ 2\text{x}10^{8}$B	$13\text{x}10^{9}$B	$43\ 3\text{x}10^{9}$B	$67\ 6\text{x}10^{9}$B	$18\ 2\text{x}10^{8}$B	$27\ 7\text{x}10^{11}$B	$3403\ 8\text{x}10^{9}$
	Processed Film	1,398,835 F	2,496 F	---	861,400 F	---	601,000 F	36,000F	2,899,731 + 75,000* 2,974,731
	Processed Hard Copy	20 P	50 P	40 P	20 P	10 P	50 P	50 P	240 P
	Support Inf	---	---	---	---	---	---	---	TBD
		Physics	Astronomy	MS&MS	Technology	Com/Nav	Life Science	Earth Resources	

B= Bits, F = Frames, P = 8½" x 11" pages
* Estimate of video frames on film

1 Stored for 45 days on-line
2 Stored for 2 years

3 100% stored for 2 years
65% stored for 10 years
15% stored forever

Figure 6.2-1 ISS Data Storage Volume for One Month

Data Category	Volume		Storage Time
	ISS	GSS	
• Raw Digital	34×10^{11} Bits	TBD	45 days
• Raw Analog	118 hr @ 10MHz	TBD	
• Preprocessed Film	3×10^{6} Frames	TBD	2-3 years
• Preprocessed Digital	34×10^{11} Bits	TBD	
• Preprocessed Analog	118 hrs @ 10 MHz	TBD	
• Hard Copy	123 pages*	TBD	
• Samples		TBD	Sent to PI, index held 4 years
• Experimenter-Processed Digital Data	34×10^{11} Bits	TBD	100% for 2 years
• Experimenter-Processed Film	3×10^{6} Frames	TBD	35% for 10 years
• Experimenter Processed Hard Copy	240 pages*	TBD	15% for undetermined amount of time

* 8-1/2" x 11"

Figure 6.2-2. Archival Storage Time

6.3 ARCHIVAL CENTRALIZATION/DECENTRALIZATION

The primary objective of this subtask was to consider the advantages and disadvantages of archiving in a data center as opposed to decentralized archival by existing government data centers or by users In performing this task, the following factors were considered user requirements, degree of centralization/decentralization desirable, and how to allocate archives

	RANGE OF RETRIEVAL RESPONSE TIMES
Documents (hard copy)	8 - 48 hours
Tapes	24 - 48 hours
Film	8 - 48 hours
Information File Retrievals (Indices, Abstracts, Production Control Reports, etc)	1 second - 6 hours

Figure 6.2-3. Anticipated System Retrieval Response Time

6.3.1 ARCHIVE BASED ON USER REQUIREMENTS

In general, most users do not have specific long term archival requirements Exceptions to this rule include astronomy and certain non-repeatable experiments The following two general user requirements have been identified

- All preprocessed experiment data must be archived until the experimenter has finished his detailed analysis and data reduction The experimenters are usually under contract with NASA for this analysis and are generally required to complete the analysis within two years Thus, the preprocessed data may be purged from storage after two years or whenever the analyzed data is received The purged data will normally be made available to the PI for retention as he chooses

- Selected experiment data must be provided with sufficient long-term storage and retrieval capability to satisfy the prime user needs

The conclusion one reaches from current and existing user requirements is that there seems to be no valid requirement for location of the archival storage based on individual users Since user needs will probably be evident after or during experiment data analysis, it is worth while considering an archival system which would be flexible enough to be responsive to these needs Such a system is described in Section 5

6.3.2 DEGREE OF DECENTRALIZATION

Space station experiments are oriented toward astronomy, material sciences, life sciences, communications, etc The responsibility for the experiments is located at many different geographical locations within the NASA organization, and users will be located throughout the world. Thus, in order to decide upon a configuration in terms of centralization or decentralization of data archives, it is necessary to examine and weigh discipline and geographical considerations. Other factors considered include data acquisition, sources of input data and the data distribution system

6.3.2.1 Geographical Decentralization

This analysis for geographical decentralization is also dependent upon the sources of input data, the acquisition and distribution of the data, user locations and system cost The primary benefits of geographical decentralization are a reduction in acquisition and archival costs and convenience for the users The principal disadvantages are more complex coordination and some duplication of storage and support activities.

Input data received at the archives will come essentially from the following sources

- NASA field offices responsible for experiments
- Experimenters (i e , PI's)
- Secondary sources (i e , users)

These sources of input data may be defined as primary and secondary Primary sources are NASA groups and experimenters working directly on the Space Station program. Secondary sources are the support groups in NASA and other governmental or industrial agencies

Figure 6 3-1 shows geographical distribution of NASA Centers and Industrials Areas Redundant acquisition of inputs, as well as distribution of outputs, would be a huge problem with this many sources and users A centralized coordination group is clearly needed within the

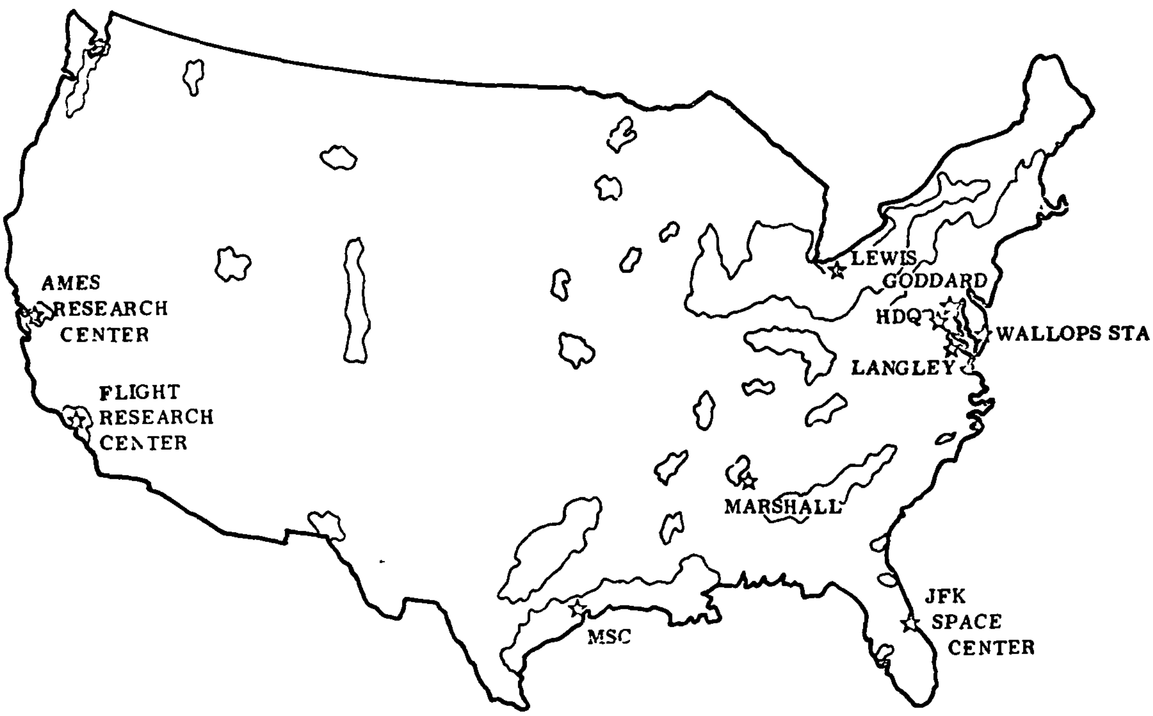


Figure 6 3-1. NASA Centers and Industrial Areas

archive system to prevent the redundant acquisition of experiment data This control will be required whether the actual distribution of data is centralized or decentralized The nature of queries for the finished experiment data will probably cut across different experiments This situation again suggests that centralized control is preferable

The distribution system must not only consider the demand for the product to be distributed, but the mechanics of distribution with respect to existing facilities The coordination required to provide deliverable data to a multitude of users across different disciplines suggests that a centralized control be maintained

The turnaround time for a data or information query is defined as being from the point of initial request until the retrieval data is ready to be shipped to the requestor (by physical or electrical means) The processing of the request, locating the data, reviewing the data, processing and packaging are included in the turnaround time Figure 6 2-3 Anticipated System Retrieval Response Time showed turnaround time based on the user requirements The short turnaround time (one second - six hours) for information-type queries calls for a centralized system to house all indexes, catalogs, data lists and similar information

6.3.2.2 Discipline Decentralization

Discipline decentralization of the space station experimental data is defined as archiving all experiment data associated with a particular discipline at existing government data centers Advantages of discipline decentralization include

- Existing data centers are organized by discipline, thus, the user community is familiar with this organization
- Less costly to expand existing data centers versus building a central facility for the slow response (24 - 48 hours) archive queries

Disadvantages of a discipline decentralized archive system include

- Some duplicate data storage will be required
- Coordination activities may be more complex

6.3.2.3 Existing Decentralization

A cost effective and user desirable method of archiving experiment data would appear to be the expansion of existing government archives that are currently handling archiving for a particular discipline In addition, a new NASA capability would be required to store all support information (indices, catalogs, data lists, automatic purging criteria, data management, etc) and act as a referral agency to the decentralized archives

6.3.3 SHORT-TERM ARCHIVAL

The short-term (45 day) archival must be made available to the preprocessing facility and therefore should not be stored on a discipline basis This data should be stored at the central facility in a manner allowing rapid retrieval for dissemination to the preprocessing system or purging

6.4 MASS STORAGE SYSTEMS CURRENTLY AVAILABLE

The following section describes two large storage systems which are currently available on the market. In both cases early models are available with specifications adequate for the NASA archival problem and are considered characteristic of the evolving state of the art in the time period in question. These two systems are Precision Instrument Company's UNICON system and the Ampex Terabit Memory System

6.4.1 PRECISION INSTRUMENT COMPANY'S UNICON SYSTEM*

This is a laser mass memory system, embodying techniques for accumulating data in a highly dense format - more than a third of million bits are packed in an area the size of a single punch on a data processing card This approach can provide on-line write and storage capacity for 10^{12} bits with a capability for rapid reading and retrieving

The mass memory system uses a finely focused laser beam to write extremely dense binary data on a special recording medium, called a Data Strip. The technique is available in two basic mass memory systems 1) with on-line capacity of 10^{12} bits and 2) with 10^{10} bits Both of these systems are called UNICON - standing for Unidensity Coherent Light Recorder/ Reproducer The first on-line system, currently undergoing software testing, was delivered to NASA Ames Laboratory in October 1971 Another is scheduled for installation with the Amoco Production Company Cost of the trillion bit storage capacity is about 0 0001 cent/ bit for the first 10^{12} bits, initially stored on-line, add approximately 0 00001 cent/bit for the essentially unlimited off-line storage

Each of these systems consists of two basic units 1) a laser recorder unit which performs the read/write functions and the physical retrieval of information from the on-line file, and 2) a recorder control unit which interfaces with the host computer and serves as the file manager A block diagram of the trillion bit system is shown in Figure 6.4-1.

The Data Strip is a polyester sheet on which a thin coating of metal is deposited by an RF sputtering process. The thickness of the costing is made to be extremely uniform in order to insure that the laser energy focused on the strip for burning a logical 1 in the metallic surface will be done without damaging the substrate The strip is 82 cm by 12 2 cm (31 25" long, 4.75" wide) and 18 mm (0 007") thick and the bit density is about 4.15 M bits/cm^2 (26 8 M bits/in^2) or about 2 88 x 10^9 bits for the entire strip

The laser recorder unit consists of a rotary file of data strips (as many as 450), a laser source and two read/write channels Each channel includes its own laser modulator, drum, and carriage with galvanometer, as well as associated electronics The rotary file, actually a carousel, houses the data strips in a vertical position The file serves both channels under control of a servo The servo causes carousel rotation either to position the proper rotary file slot for receipt of a data strip dismounted from the drum or to accurately position a data strip in the rotary file for mounting on the drum Any strip in the rotary file can be selected for mounting on either drum in less than nine seconds The beam from the laser source is initially split to two modulators, each of which, together with appropriate optics, provides control of the light intensity for each unit Each modulator functions like a shutter, maintaining the laser light at a fixed level until a logical one is to be written The "shutter" then opens and the beam is intensified The beam is reflected by a system of stationary mirrors to the moveable carriage, which through its galvanometer-controlled mirror reflects the beam onto the data strip. The carriage moves back and forth across the data strip

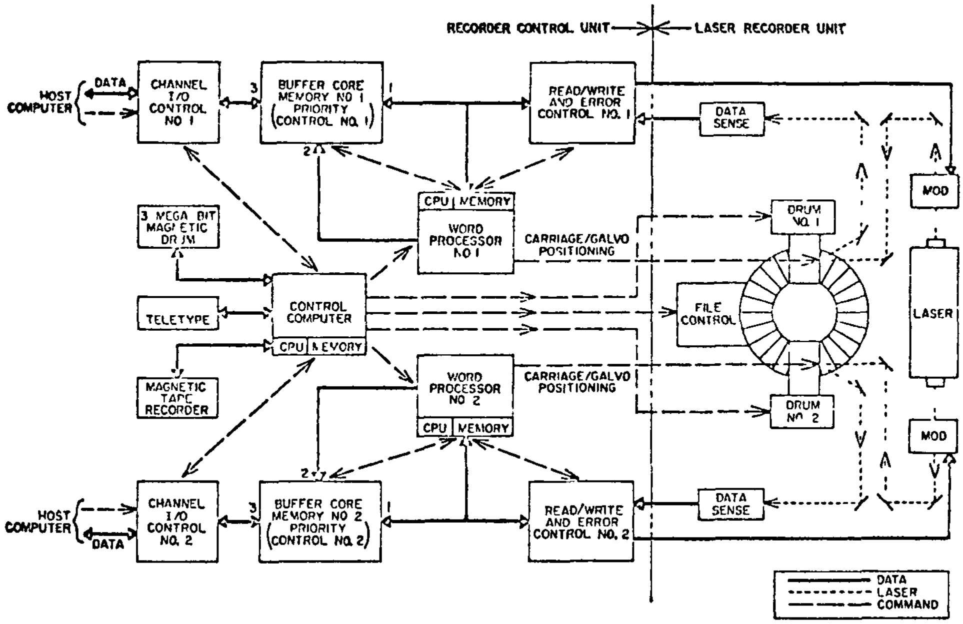


Figure 6.4-1. Simplified Functional Block Diagram

When the modulator intensifies the laser beam to write a logical one, the high energy focused on a small spot vaporizes the metallic surface The metallic surface reflects 50% of the incident light, whereas vaporized areas reflect only about 5% This difference in energy of the reflected beam is used in the read mode (low energy)

A data sheet of information compiled from a number of sources about the UNICON system is shown in Figure 6 4-2 However, in addition the following miscellaneous additional information is listed

1 Twenty to thirty per cent of the memory capacity is used for error control, so that the effective capacity is 7×10^{12} bits

2 The on-line system prices include software for interfacing with IBM and PDP machines

3 Cost of each strip is approximately \$40 or about 2×10^{-6} c/bit

4 There is essentially no degradation of the strip with time

5 Total floor space requirement is about 18 m^2 (200 $feet^2$) of which 5 4 m^2 (60 $feet^2$) is for equipment

6 System access times are as follows

Access to a strip - eight seconds

Random access to mounted strip - 200 ms

When track is found, essentially sequential access

7 As a stand alone device it would need two people/shift, one operator and one clerk In a data processing installation, no additional personnel are required

8 It takes 10 5 minutes to prepare two data strips concurrently

Attributes	Item Value	Comments
Storage Medium Character		3 software systems - host
Density bits/in^2	2 8 X 10^6	computer, control computer,
Physical Dimension	31 1/4" X 4 3/4"	data-control function 450 strips,
Error Rate	1 in 10^9	each strip 200 X 10^6 bytes
Life	permanent	
Degradation		
Medium Cost c/bit	10^{-6}	From drum, electro-optic category
Medium Access sec	15 X 10^{-6} 150 ms	within strip access to any strip
System or Equipment Charac		
Volume bits/in^3	8 X 10^8	
Storage Capacity bits	10^{12}	Also 10^{10} on-line
System Access sec	9	
Data Rate bits/sec	4 X 10^6	Transfer to buffer
System Cost c/bit	1 X 10^{-4}	Have heard 1 6 X 10^{-4} (i e $1 6M - NASA, NBS)
Application Suitability		
Processing Working Storage		
Display		
Archiving	x	
Other Parameters		
Development Status	P	
Refreshment Frequency		
Error Correction	x	Split prism
Reliability	Not as reliable as magnetic	
Date of Availability	1971	First system delivered to NASA/Ames in Oct 1971
Read/Write	Yes	Destructive Write
Equipment Cost	$200K	
System Cost	$1 6M	
Medium		Metal data Strip

Figure 6 4-2. UNICON Specifications

6.4.2 THE AMPEX TERABIT MEMORY SYSTEM

The Terabit Memory (TBM) is an erasable, updated digital memory The system is modular providing on-line storage capacity up to 3×10^{12} bits (3 trillion bits) with data throughput of maximum of 36×10^6 bits/second The basic storage medium is ultra high density (UHD) magnetic tape with each reel containing as many as $1\ 1 \times 10^{11}$ total number of bits (effective usable storage of 5×10^{10} bits) of which there can be an unlimited number in off-line storage. Information is stored by using video recording techniques – i e it is recorded transversally normal to the direction of motion of the 5 08 cm (2 inches wide) tape, rather than by the more conventional longitudinal recording in which the information is recorded parallel to the motion of the tape Longitudinal address tracks identify blocks of data These addresses are read during high speed search The high packing densities achieved with transverse recording, combined with search speeds of 2540 cm/second (1000 inches/second) give the memory random access characteristics

The entire memory is under control of a general purpose digital computer This computer provides a command, status and control interface with the host computer served by the memory The control computer can also be programmed to emulate a standard peripheral so that to the host computer, the TBM can be made to look like a large number of on-line disc files, strip files or tape transports Specifications are shown in Figure 6 4-3

The TBM manufacturing prototype system was completed in the latter part of 1970 and is in operation at Ampex's Sunnyvale facility A system that is scheduled for delivery early in 1972 has been partially assembled at Sunnyvale This system has a total storage capacity of $1\ 7 \times 10^{12}$ bits, 18 transport modules (i e 36 tape units) with a maximum throughput of 24×10^6 bits/second Experience with this system has shown a data accuracy of 1 in 10^{11} It has been stated that tapes can be stored as long as ten years without the necessity for refreshment System prices range from about $425K to $3 million

6 5 CANDIDATE CONFIGURATIONS AND COSTS

In the last subtask of the Archival Study, the data flow in the archival system was developed, a number of candidate configurations were investigated, and two were selected for detailing of equipment requirements and estimation of costs

6.5.1 ARCHIVING DATA FLOW

Based on the requirements for data archival and retrieval discussed earlier, the flow of data through the archival system was determined and the functional steps in the process defined A diagram illustrating this flow is shown in Figure 6 5-1 The figure is divided into three parts The section on the left shows all the data inputs received by the archiving system from the Data Reduction Facility, where they have been decommutated, edited and split by experiment Coded symbols have been used for the inputs, e g RD signifies raw digital data User requests are also inputs to the system as are interactive queries (e g from users at I/O terminals). The central area depicts the functions performed by the archiving system, while on the right are shown the output products and their disposition (copies to users, masters back to archives) The input data coded symbols are shown as they apply individually to each of the functional blocks shown in the central area and in the section to the right

Attributes	Item Value	Source	Comments
Storage Medium Character			
Density bits/in^2	1.42×10^6	33	Effective $7\ 1 \times 10^5$ bits/in^2 or $1\ 1 \times 10^5$ bits/cm^2
Physical Dimensions	2" tape	35	Length of reel 40,000 in
Error Rate	1 in 10^9	33	2-channel redundancy
Life			
Degradation	no		
Medium Cost c/bit	10^{-6}	33	UHD tape
Medium Access			
System or Equipment Char			
Volume	7 ft^2/rack		
Storage Capacity	$1\ 1 \times 10^{11}$	-	Effective 5×10^{10} Expandable in 10^{11} modules
System Access Sec	2-3		
Data Rate bits/sec	6×10^6	33	Max of 36×10^6 bits/sec
System Cost c/bit	10^{-4}	33	Throughput
Application Suitability			
Processing			
Display			
Archiving	x		
Other Parameters			
Development Status			2 systems at Sunnyvale
Refreshment Frequency		none	-
Error Correction	Yes	33	
Reliability	Good	33	In 24 hr , 5 min hardware downtime with scheduled 2 hour maintenance
Date of Availability	197		
Read/Write	Yes	33	
Equipment Cost	\$425K - 1 3M		

Figure 6.4-3. Ampex Terabit Specifications

The main point that emerges from the figure is that basically the same set of functions are performed on all the data inputs These functions are seen to be the creation of indexes and abstracts by a manual/machine-process (manual keyboard entry using I/O terminals and displays), storing the information in on-line mass storage, search of the abstract file in response to user requests, the computer generation of applicable correlative terms for the user requests, viewing of abstracts by the users in an interactive mode or a browsing function, and the periodic refreshment of magnetic tape files from archives (this is the only function that is unique to this data input form)

This composite flow-chart combined with quantitative data loads served as the basis of the analysis and selection of candidate archival system configurations The remainder of this section reviews, in some detail, the archival data flow and functions

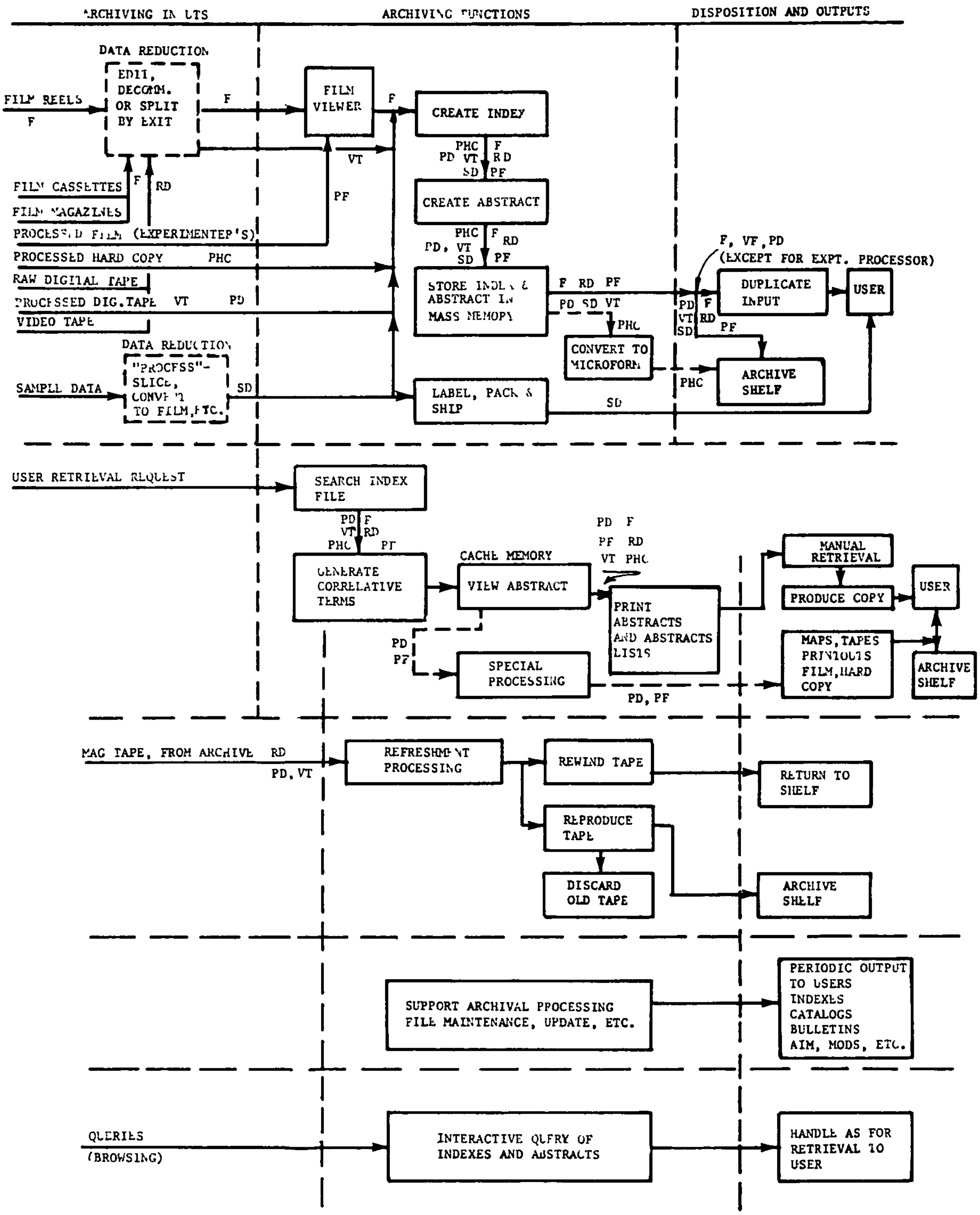


Figure 6.5-1. Archiving Data Flow

Figure 6.5-1 illustrates the complete input, user access and retrieval data flow for the information retrieval and data archive systems Several types of data are candidates for storage in the system, including 1) indexes and abstracts of the archival data, stored in the mass memory information system and 2) the original film, digital and video tapes and hard copy are physically stored in the slower access archives Physical samples will be indexed, but the actual samples will be sent to the experimenters and not stored at the archives. Categories of input data include 1) data that has been preprocessed (i e edited, decommutated, split by experiment, etc) and 2) experimenter processed data, which includes reduced and final analyzed data Once data has been received it will be forwarded to a data analysis and technical writing group This group will be responsible for the generation of indexes, abstracts, catalogs, etc and file maintenance The indexes, abstracts, etc will be produced manually, but with computer assistance (I/O alphanumberic keyboard, CRT display, etc.).

File maintenance consists of updating the various information files, refreshment processing of magnetic tapes, and planning and performing purge of the archives File maintenance will be aided by an operational review of usage statistics about data inqueries, data found by a search, data requests, data selected after the review by the user, etc. From a review of this computerized usage statistics, indications can be made concerning system planning, modifications in the storage and retrieval concept such as the sources update, index modifications, data base modifications, etc

Figure 6 5-1 also shows both inquire and request data flow A fundamental difference between inquiries and requests (queries) is the actual data retrieval The indexes, abstracts, etc which will be accessed by a data inquiry will be stored in on-line mass memory, while the actual bulk archival data which would be accessed by a data request would be stored physically in the archives All inquiries and retrieval will be handled by a data coordination group which would work closely with data analysis and technical writing groups

Following machine retrieval of inquiry type data, compilation is required to prepare the assembled data for distribution This consists primarily of converting the electronically stored data into hard copy

The retrieval and compilation of request data and the copying of pre-processed input data for shipment to the experimenters will involve the handling of large quantities of data and types of media After location of the material, personnel will have to retrieve, handle and copy such diverse and incompatible media as magnetic tape, microform data, hardcopy film, photographs, and document hardcopy

Data file conversion and specialized processing may be required if the archived data is to be beneficial to a broad range of users The media, codes and languages of data storage within the system are not necessarily those being used by the users' data processing facilities Also, the user with a specialized installation will probably not have the required means of data file conversion at hand

Data distribution can probably be performed as a mailroom operation for the initial system Following the growth of the archives and information systems, it may be necessary to expand to the extent where it could be assembled by a separate distribution agency

6.5.2 CANDIDATE CONFIGURATIONS

In this section a number of degrees of centralization/decentralization of the information

retrieval and data archiving function are considered, and two basic configurations are selected to be examined in further detail These configurations (A and B) are discussed along with a special case of Configuration A

6.5.2.1 Selection Factors

One of the basic choices in the development of the organization and integration of the information cataloging indexing retrieval system and the archive system is the degree to which the systems will be centralized Figure 6 5-2 shows the primary data center/experimenter tradeoffs based on the degree of centralization If both centralized information and archive systems are decided upon, a new organizational structure will have to be created. No single organization exists at the moment that encompasses the full scope of an information and archive system discussed here Since each of the existing organizations covers only part of the system, centralized systems would have to duplicate many of the functions of the existing organizations A centralized archive and discipline-decentralized information system is not adequate because distributing the functions of cataloging, indexing and abstracting on a decentralized basis with a central archive would make a very clumsy information system for the users

As column three in Figure 6 5-2 suggests, any form of archival by the experimenter is inadequate due to the great number of experiments in the program (around 75 at present) This many sources would result in unwieldy and difficult retrieval, lack of uniformity of the systems with an apparent problem of coordinating 75 or more archives

As indicated in Figure 6 5-2 the most desirable systems from a requirements point of view include a discipline decentralized archive with either a decentralized or centralized information system The decentralized archive has the advantages of

- utilizing existing systems that could carry the additional loads with little to moderate modifications
- the majority of the user community being adjusted to and familiar with the current discipline organized archive data centers

Although either centralized or decentralized information systems are feasible, from a convenience and requirements point of view the centralized system would be the most desirable system based on the following factors

- A centralized coordination group is clearly needed to prevent redundant acquisition of the experiment data
- Queries for the finished pertinent data will probably cut across different experiments which would suggest that centralized control is preferable
- Queries may also cut across disciplines, which again suggests that centralized control is preferable

6.5.2.2 Configuration A

This configuration, shown in Figure 6 5-3, Configuration A Control Catalog and Figure 6 5-4, Configuration A Control Archival Configuration consists of a cataloging facility and a number of data archival facilities described below

ARCHIVES

- Data/Film Storage
- Physical Retrieval
- Copy and Reformat
- Refresh

		CENTRALIZED	DECENTRALIZED BY DISCIPLINE	DECENTRALIZED BY EXPERIMENTER
CATALOGING AND ABSTRACTING • INDEXING • ABSTRACTING • INFORMATION RETRIEVAL • USER ASSISTANCE	CENTRALIZED	• DUPLICATES NASA AND OTHER AGENCY FUNCTIONS • COSTLY-DOES NOT UTILIZE EXISTING FACILITIES	CONFIG. A	• UNRELIABLE STORAGE • TOO MANY SOURCES-HARD TO RETRIEVE DATA
	DECENTRALIZED BY DISCIPLINE	• IMPRACTICAL TO DISTRIBUTE CATALOGING WITH A CENTRAL ARCHIVE • MORE DIFFICULT FOR USERS - HARD TO LOCATE DATA	CONFIG. B	• UNRELIABLE STORAGE • TOO MANY SOURCES - HARD TO RETRIEVE • POOR CONTROL

Figure 6 5-2. Data Center/Experimenter Trade-Offs

1 A centralized Indexing and Abstracting Facility (here called Central) is required in which all the indexing, abstract creation and information retrieval functions are performed The term information retrieval is used to distinguish between 1) the physical retrieval from archives of documents or data requested by a user, and 2) the process of computer search to identify the desired data and locate where it is stored--hereafter referred to as information retrieval Thus, the centralized facility in this configuration performs only the latter function (i e , information retrieval), and in doing so services all user information requests When a search is completed, the user receives abstracts of the appropriate documents with their locations at the archives which are housed non-centrally by discipline in a number of data centers All inputs--UHD tapes, computer compatible digital tapes, video tapes, movie and roll film in various sizes-- are received by this location after they have been edited and grouped by experiment The central facility makes a copy of these input forms which it ships to the appropriate experimenter and sends the originals to the data center responsible for that discipline

While it would be possible to have the preparation of copies for the experimenters done in the Data Reduction Facility, this function has been included in the information retrieval

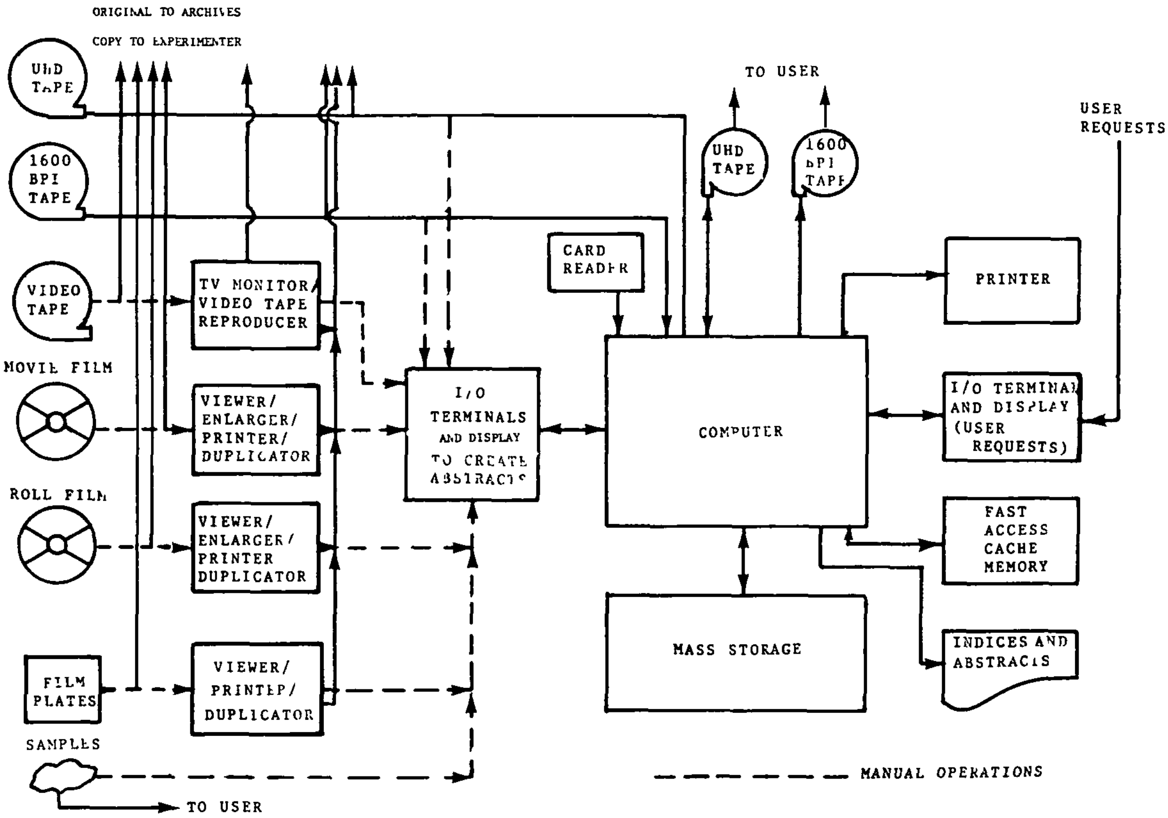


Figure 6.5-3 Configuration A – Central Catalog

system to facilitate control in the generation of the index and abstract file

With this configuration is is not necessary to archive any data (except temporarily for control) at Central The required equipment, therefore, consists of film viewing, enlarging, duplicating and printing equipment, I/O terminals and displays for the creation of abstracts and the processing of user requests The terminals would also be available for users for browsing through the abstract file and selecting abstracts of interest for which the computer identifies the location in a data center archive It is proposed that the abstracts be stored in a two-stage memory system, both on-line for quick access 1) a fast (of the order of 100 ms) direct access memory for active or current abstracts and 2) a slower access (of the order of 10 sec) mass storage (e g trillion bit storage) which stores cumulatively all abstracts as they are received. Periodically abstracts would be transferred from the direct access storage to the mass storage Figure 6 5-4 also shows the central computer with associated equipment such as card reader, printer and tape drives Special equipment would be needed for the handling of UHD tapes

A special treatment is accorded samples received from the space station These will have been "processed" in some appropriate fashion (such as slicing, etc) in the Data Reduction Facility. At Central, abstracts are created for these samples, after which they are immediately shipped by the interested experimenters

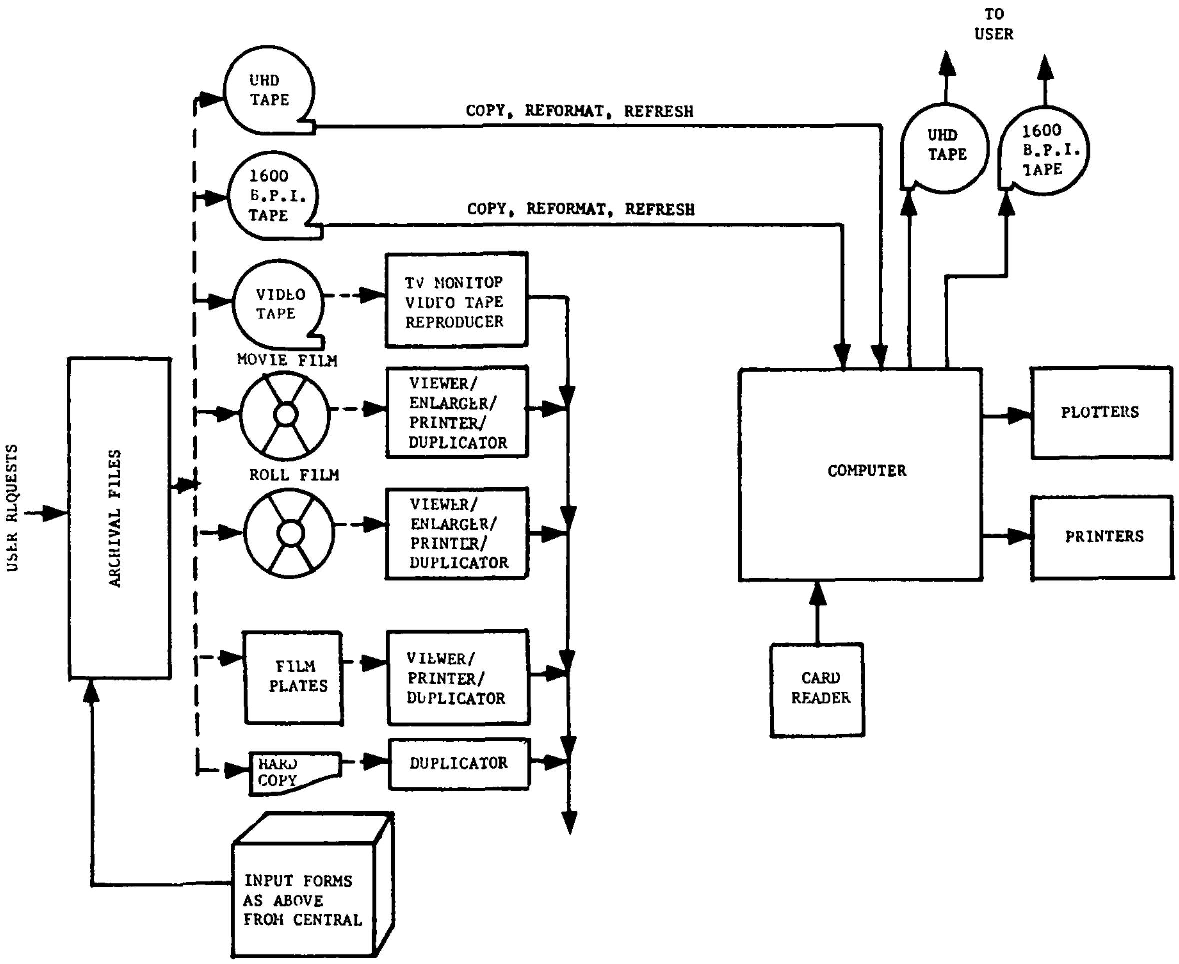


Figure 6.5-4 Configuration A – Central Archival Configuration

2 Several discipline-oriented Data Centers (DC) are suggested, which archive separately all the experiment data received from Central. The configuration layout for these data centers is shown in Figure 6 5-4 The principal function of the centers is to physically retrieve documents from their separate archives on the basis of the location identified by Central in the user request Some of these requests will be for information contained in the tape archives and may require some computing and reformatting and will therefore require the aid of the computer in each installation Other requests will be for film which will require duplication, processing and printing, and therefore are serviced by physical retrieval of the data from archive, copies made, and the archive master returned to file Hardcopy requests are similarly handled Periodic refreshment of tapes will be performed by the centers, possible maps generated, manuals and bulletins, etc

No abstracts are housed in machine storage at these centers, (in contrast to the mass storage needed at Central) although catalogs and listings will have been furnished for them by Central This arrangement minimizes the size of the computers required since the machine search to locate the data desired would not be necessary The configuration layout in Figure 6.5-4 therefore includes no mass storage and no terminals since user information requests are serviced by Central Much of the equipment at the centers consists of reproduction

equipment for film, video tapes and hard copies Only the Earth Science (ES) Data Center required UHD tape equipment because only ES experiments generate this type of data

6.5.2.3 Configuration B

In essence this configuration (Figure 6 5-5 Configuration B) combines all functions of Configuration A and performs them at the five discipline-oriented data centers In other words this configuration decentralizes the information retrieval and cataloging functions as well as the archival functions. Each data center performs its own separate indexing, separate abstract creation, separate information retrieval, and separate physical document retrieval from its own discipline-oriented archives It services all user requests in its own discipline area, and duplicates and/or reformats documents from archives as requested by a user

Since the Earth Sciences (ES) discipline generates 80-85% of the total experiment data load, the capabilities of the data center for this discipline will be much greater than for the other centers in order to handle the same large percentage of total user requests This factor is taken into account in the sizing of the installation in the succeeding sections Another difference of the ES discipline is that it is the only one that generates multispectral sensor data which is written on UHD tapes at the Data Reproduction Facility and sent to the ES Archives Consequently as shown in Figure 6 5-5, the ES Data Center is the only one of the five data centers which will have a requirement for mass storage (to service 80% of user requests, or 320 per day) and UHD tape equipment As for Configuration A, all equipment shown in the figure is currently available, except for the UHD tape on-line entry to and output from the computer It is projected that this type of equipment will be available off the shelf in the time frame of the Space Station Program.

In this decentralized configuration, the dissemination of the data to the discipline-oriented data centers will have to be done by the Data Reduction Facility (DRF) In other words the original data as prepared by the Data Reduction Facility will be sent directly to the appropriate discipline-oriented data center At each center these originals are duplicated in order to prepare a copy for direct transmittal to the experimenters The originals are then stored in the center's separate archives In contrast to Configuration A which had all its I/O terminals for index and abstract creation and the servicing of user requests at the Central Facility, in Configuration B each of the separate data centers will have its own such terminals

6.5.2.4 Special Case of Configuration A

Reference has already been made to the fact that about 80% of the total data is generated by the Earth Sciences discipline Hence the vast majority of the data will be archived at the ES Data Center. This suggests a special case of Configuration A, which would have economic advantage, i e , co-location of the ES Archival Data Center of Configuration A with the Central Cataloging and Abstracting Facility of the same configuration For this case, it becomes possible to consolidate some equipment such as the computers and the UHD tapes Other economies are also possible in the film and reproduction equipment In concept this special case is exactly the same as described for Configuration A and is only different in that the Central facility and the ES Data Center are co-located. Should this case be selected it would have the added advantage of being convenient to users, in that most (i e , 80%) user requests, whether for abstract information or for actual copies of documents or data from archives, will be serviced from the location where the data is physically stored No new configuration layout is necessary and Figures 6 5-3 and 6 5-4 apply to this special case also

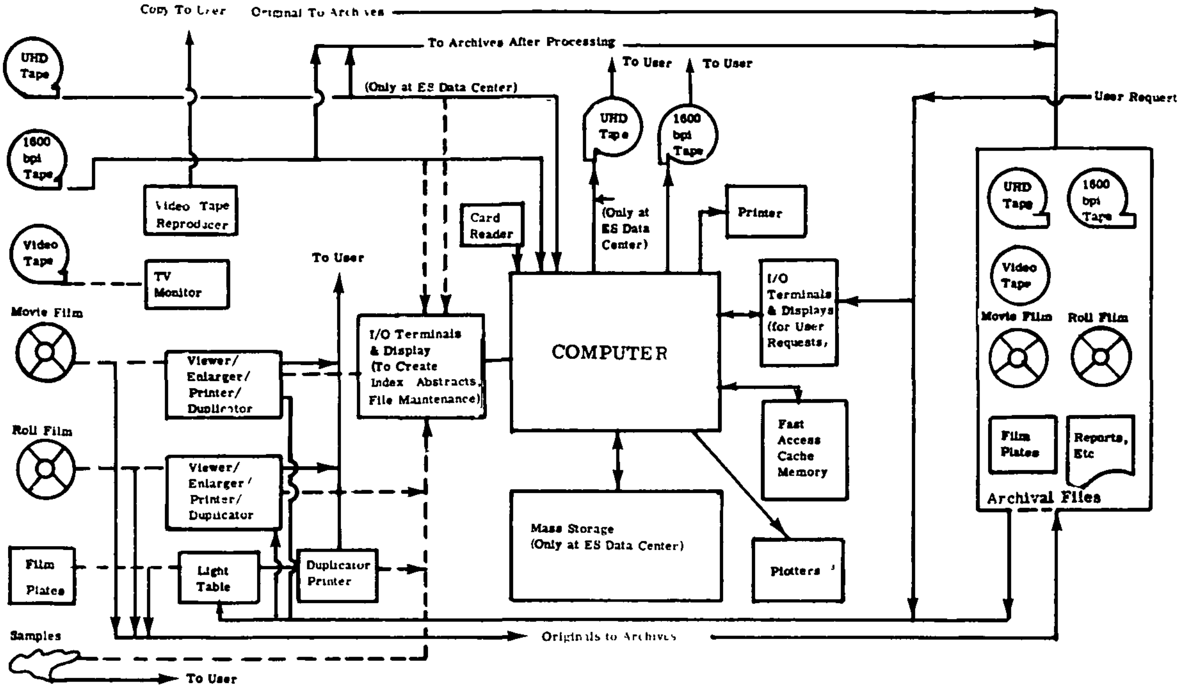


Figure 6 5-5 Configuration B

6.5.3 EQUIPMENT SIZING AND COST ESTIMATION

The candidate configurations described above were analyzed to determine the sizes or capabilities of equipment needed and to estimate their costs The estimates developed reflect the magnitude of the parameter rather than details (e g , procurement) specifications or costs One of the first considerations in the analysis was to determine the number and size of abstracts required for the Archival System.

6.5.3.1 Index and Abstract Size

The volumes and types of experiment data received from the Space Station have been discussed in Section 2 of this report This information was used to estimate the daily indexing and abstracting load for the principal data types A number of assumptions were necessary, and are stated at appropriate places in the discussion that follows. The principal assumptions can be summarized as follows

a. Whereas retention criteria have been established (Section 2) for the various data types, e.g , the retention of only 35% of the experimented processed data for 10 years, it will nevertheless be necessary to keep abstracts indefinitely on file for any data that is purged These abstracts will not only have a summary description and identification of the data but will also indicate their disposition (e g , which experimenter, user, or group may now have them) once they are eliminated from the archives Therefore the index and abstract file is visualized as a continually growing file.

b Experimenter processed data was assumed to be received by the archival system within 2 years after generation of the data in the Space Station

c Experimenter-and user-processed data were assumed to be about equal in volume to the amount initially sent to the experimenters This ratio may seem high, based on past experience, but most of this data will be for the ES discipline and it is expected that user interest will be very high

d Frequency of daily access to the data base and hence to the abstracts, will be up to 20% of the user population (the maximum of 2000 is used herein to obtain worst-case estimates of cataloging loads) accessing 5% of the total data base

6.5.3.1.1 Hard Copy Abstracts

The abstracts for this data form will be mostly textual (e g , for reports) and therefore will be relatively long On the basis of experience with a number of systems such as the N Y Times Information Bank the number of abstracts at the end of 2 years is estimated at 590, and each abstract would have provision for up to 500 words or one page

6.5.3.1.2 16mm Movie Film

It is expected that the abstracts will textual and long for any single reel It is assumed that this film will be supplied by the Data Reduction Facility spliced to contain only one experiment per reel Assuming that the reels average 150 meters in length, it is estimated that 18 5 reels will be generated per month The length of each abstract is estimated to be 500 words maximum After 2 years the number of abstracts generated will reach about 4440

6.5.3.1.3 35 mm Film

It is estimated that 94% of this film will be motion picture film and the remainder will be 35mm frames It is assumed that the movie portion will be handled as described above for the 16mm film The number of abstracts after 2 years is estimated at 2860 In the case of the frame film, it is assumed to be stored in roll form However, since the number of frames of this size film as well as for the other sizes is very large and constitutes the major abstract load on the system, the abstract size and number are estimated differently It is expected that there will be many overlaps in the frame film generated, possibly multiple copies of the same scenes on the frame could be contiguous so that several could be described by one abstract For these reasons it is estimated that on the average, one abstract will be sufficient for 3 frames Again on the average these abstracts should have at least 5 identifying parameters - discipline, experiment, time, the corner geographical longitudes and latitudes Provision is made for each abstract to be 300 characters long Thus it is estimated that the number of abstracts at the end of 2 years will be 48,000 for the 35mm frame film

6.5.3.1.4 70mm Film

This size film contains stellar camera information and is in frame form Only the uncorrected film is stored in the archives, since the correction process done by the Data Reduction Facility is only for the purpose of determining the attitude for the metric camera data The ES

discipline generates 25% of the total so that the ES output is then multiplied by 4 to arrive at the total number of frames Using the same considerations for estimating the number and size of abstracts as for the 35mm frame film, at the end of 2 years, the number of abstracts is expected to be on the order of $9\ 1 \times 10^5$

6.5.3.1.5 240mm Film

Both the uncorrected and the corrected metric camera frame film will be stored in the archives All this film is generated by the ES discipline On the same basis as before for frame film, the number of abstracts is estimated at $1\ 14 \times 10^5$ at the end of 2 years

6.5.3.1.6 Video Tapes

In the case of tapes (both video and digital) the abstracting scheme assumed is to have one long abstract for each reel of tape The abstract will have sufficient information in it to be able to extract a particular scene or number of scenes within a reel whenever requested by a user The size of this abstract is estimated at 500 words maximum At the end of 2 years the number of abstracts is estimated at 1448

6.5.3.1.7 Digital Tapes

The digital tapes stored in the archives consist of 2 types 1) UHD tape and, 2) computer-compatible 1600 bpi magnetic tapes The Data Reduction Facility output of UHD tapes is approximately 111 per month, for the MSS data, 9 computer tapes for the MSTV data, 8 tapes for the scatterometer and 1 tape for the microwave scanner Of the total output, 85% is estimated to be for the ES discipline On the same basis as for the video tape, it is estimated that 3100 long abstracts will be generated at the end of 2 years

6.5.3.1.8 Samples

Abstracts will also be needed for this input form, but these are expected to be minor in number, and size

6.5.3.1.9 Total Number of Abstracts

The total number of abstracts discussed above is summarized below in Table 6 5-1

Table 6.5-1. Number of Abstracts After Two Years

Hard Copy	590
Film	
16mm Movie	4,440
35mm Movie	2,860
All size frames	1,070,000
Video Tape	1,448
Digital Tape	3,100
Total	1,082,438

As stated in the assumption, the experimenter-processed data are assumed to be equal to the inputs received, so that the total number is doubled or in round numbers a library of 2 million abstracts is anticipated after 2 years of operation

6.5.3.1.10 Daily Abstract Rate

Using the frequency of access criterion stated in Section 5 3 1, the daily number of abstracts accessed by the computer in the search made would be about 100,000 from 400 user requests Of this number of abstracts accessed it is estimated that 20% or 20,000 abstracts per day will be supplied to the users in the form of printouts

6.5.3.2 Mass Storage Requirements

At the Central Facility of Configuration A and at the ES Data Center of Configuration B, there is an estimated requirement to service daily 400 or 320 requests for information retrieval, respectively Access times to the abstracts for these requests will vary from seconds (for browsing requirements to the I/O terminals) to as much as 48 hours Also these requests could access 5% of the total abstract base daily To meet these requirements, on-line storage of abstracts is essential One way of meeting the requirements is to have a two-stage memory system, both stages on-line. The first stage would consist of a fast direct access memory (e g , disk with average access times of less than 100 ms) which would store the "active" indexes and abstracts The active file would grow to a 2-year volume of abstracts After this period transfer of the abstracts would be made to the second stage mass storage with access times of the order of 10 secs (e g , Ampex Terabit or Precision Instrument Co 's UNICON) which would then grow cumulatively as the transfer of abstracts is made to it from the fast access memory The fast access device would be continually replenished with new abstracts

Based on the estimates made in the previous section of the number of abstracts, the need for mass storage for the second stage is indicated by Table 6 5-2 which shows the index abstract build-up after 6 and 10 years It has already been stated that even though there are criteria for the purging of archival data, the abstracts themselves will be retained so as to keep on record the disposition of the data (i e , to whom they were sent) and what they contained As indicated by the table, an on-line storage capacity of $1\ 5 \times 10^{10}$ bits after 6 years and $2\ 6 \times 10^{10}$ after 10 years will be needed These figures could even be on the low side if a more complex indexing and abstracting system is implemented, if each abstract should require more than the number of characters that has been estimated, or if a single abstract is required for each film frame rather than the average of 1 for 3 assumed

6.5.3.3 Computer Sizing and Cost Estimates

As stated in Section 6 5 3 1, the sizing analysis was based on the daily loads after the first two years to allow for the experimenter-and user-processed data (for which abstracts would be created)

6.5.3.3.1 Central Facility - Configuration A

The basic daily loads and functions of the computer at this facility are estimated to be the following

Table 6 5-2. Storage Volume for Indexes & Abstracts in Bits

	6 Years	10 Years
Hard Copy	6 2 X 10^7	11 2 X 10^7
Film		
16mm Movie	62 X 10^7	111 6 X 10^7
35mm Movie	40 X 10^7	111 6 X 10^7
Frame Film	1280 X 10^7 *	2294 X 10^7 *
Video Tape	20 X 10^7	36 X 10^7
Digital Tape	43 X 10^7	78 3 X 10^7
Sample	Same	Same
Other	Same	Same
Totals	1451 2 X 10^7	2603 1 X 10^7

* 1 abstract assumed for 3 frames

a Service 400 user requests for information retireval

b Create or update 4000 indexes and abstracts for new data inputs as well as experimenter and user processed data

c Print 20,000 abstracts from a file of over 2 million

d Transfer 2000 indexes and abstracts from the fast direct access storage (e g , a disk) to on-line mass storage

e Copy UHD and computer compatible tapes

f Other support functions

Estimates of instruction counts for the above function and loads were based on experience with a number of projects having similar functions such as the New York Times Information Bank, an Air Force tactical and information processing system, as well as IBM experience with its own information retrieval program products In some cases figures were obtained from actual tests, and in others instruction counts for specific functions For a computer with a processing capability of 200,000 instruction per second (i e , 200 KIP) the following overall estimates were arrived at

CPU Time on 200 KIP computer	= 3 hours min/day
Computer I/O Time	= 7 hours min/day
Preventive maintenance	= 2 hours min/day
Throughput Time	12 hours min/day

A 2 shift operation on the computer is therefore recommended It is to be noted that special equipment will be needed for reading from and writing to UHD tape equipment While this equipment is not currently available on the market, it is projected that such equipment will be available during the Space Station time frame The required channel data transfer rate was estimated at 3×10^6 bytes/sec

Cost estimates of the computer associated equipment for this facility are as follows

1-200 KIP Computer	$ 600,000
(Plus 500 K bytes core and channel equipment)	
2 sets of UHD tape controllers and 4 drives	400,000
16 I/O terminals and displays	80,000
1 Computer compatible tape controller and 3 tape drives	100,000
1 Line Printer and 1 Card Reader	100,000
1 Direct Access Storage with 800M bytes	300,000
1 On-Line Mass Storage	1,600,000
Total Cost	$ 3,180,000

6.5.3.3.2 Earth Sciences Data Center - Configuration A

The functions to be performed at the decentralized archiving center are the same for all the five discipline-oriented data centers However the ES Data Center, having by far the greatest loads in terms of user requests for document retrieval and the vast majority of data stored, is considered separately for sizing and estimating the cost of its computing equipment The daily computer loads are estimated as follows

a Service 320 user requests for physical retrieval of data and documents

b Physically retrieve 36 tapes/day for copying and reformatting according to user request It is estimated that this load represents 64,000 scenes of information, assuming each UHD tape to be 10,000 feet long

c Refreshment of inactive tape archives

d Support functions

The CPU time for the above functions will be minimal-of the order of 1 hour for a machine somewhat smaller than a 200 KIP computer However, the computer I/O time will be over 9 hours, so that with allowance for preventive maintenance 2-shift operation is again recommended (two shifts are necessary in any case in order to handle the heavy film duplication function in support of user requests) Computer cost estimates are as follows

1 Computer, 200 KIP with 100K bytes core, and 3 X 10^6 bytes/sec I/O channel	$200,000
1 Direct Access storage 1M bytes capacity	75,000
2 sets of UHD tape controllers and 4 drives	400,000
1 computer compatible tape controller and 3 tape drives	100,000
1 Line Printer and 1 Card Reader	60,000
Total Cost	$835,000

6 5.3.3.3 Other Data Centers - Configuration A

The function of the other 4 discipline-oriented data centers are essentially the same as for the ES Data Center but the daily loads are much smaller The main difference in that there will be no UHD tape equipment at these centers It is estimated that the daily load will be approximately the same for each center and will consist of 20 user requests, accessing, reproducing and reformatting will be from about 20 magnetic tapes This load is very light and could be handled as an additional processing requirement of existing capabilities at the data centers However, if handled as a new requirement, a small standard processor of the order of 40 KIP would be sufficient for 2 shift operation which would be needed to handle the film duplication function Cost estimates are therefore as follows

1 Small Standard Processor with 16K bytes core	$ 45,000
1 Printer and 1 Card Reader	36,000
1 Computer compatible tape controller and 4 drives	47,000
Total Cost per Center	$128,000

6.5.3.3.4 ES Data Center - Configuration B

The ES Data Center daily load in this configuration can be viewed as the handling of 80% of the load of Central and the total load of the ES Data Center in Configuration A Here economies of the combination of the two functions are realizable It is estimated that through scaling down the user information retrieval requests to 320 per day and adding the other loads, the same computer size (i e , 200 KIP) can handle the total requirements in a full 2-shift operation rather than 12 hours total It is anticipated that the number of I/O terminals and displays will be much reduced since they can serve a dual function by being used in index and abstract generation as well as for user/computer interaction Costs are therefore estimated as follows

1-200 KIP Computer with 50K bytes core, and 3 $\times$ 10^6 bytes/sec I/O channels	$ 600,000
2 sets of UHD tape controllers and 4 drives	400,000
8 I/O terminals and displays	40,000
1 Computer compatible tape controller and 3 tape drives	100,000
1 Line Printer and 1 Card Reader	100,000
1 Direct Access Storage with 800M bytes	300,000
1 On-Line Mass Storage	1,600,000
Total Cost	$3,140,000

6.5.3.3.5 Other Data Centers - Configuration B

Computer sizing is based on 1) equal handling among the 4 remaining discipline-oriented data centers of 80 daily user information retrieval requests, 2) 20% of the remaining functions of Central, and 3) all of the Data Center functions of Configuration A This implies that each data center will now process daily 20 user requests (for information and document retrieval) and the creation and update of 200 indexes and abstracts There will be no requirement, however, for either mass storage or I/O terminals (as in the case of the ES Data Center) Documents can be retrieved manually from the center archives Here again it is estimated that a small standard processor of the order of 50 KIP processing speed should adequately handle the data processing loads On this basis the cost breakdown for each center is estimated below As stated earlier this load can probably be handled as an additional requirement to existing capabilities at the present data centers

1 Small Standard Processor with 16K bytes core	$ 45,000
1 Printer and 1 Card Reader	36,000
1 Computer compatible tape controller and 4 drives	47,000
1 Direct Access Storage with 5 5 $\times$ 10^6 bytes	25,000
Total Cost	$153,000

6.5.3.3.6 Special Case of Configuration A

The ES discipline generates by far the greatest part of the experiment data load, which leads to a special case of Configuration A, i e , co-location of the ES Data Center with the Central Cataloging and Abstracting Facility Sizing estimates show that the combination of these functions can be handled on a full 2-shift basis by the same size computer (200 KIP) and associated

equipment as for Central in Configuration A, except that now a higher speed I/O channel rate (4.5 x 10^6 bytes 1 sec) will be required Hence the equipment list would be the same as shown for Central in Configuration A, but the cost would be about $100K more, or a total cost of $3,892,000 The co-location has the advantage that all user information retrieval requests would be serviced centrally Since 80% of these requests are for ES, most of the physical document retrieval load can be also accomplished in the same center at the same time

The cost estimates discussed above have been consolidated in Table 6 5-3

Table 6. 5-3. Computer Associated Equipment Costs In Thousands of Dollars

	Configuration A			Configuration B		Special Case of A	
Equipment	Central	ES	Other DC (Each)	ES	Other DC (Each)	Central ES	Other DC (Each)
Computer	600	200	45	600	45	700	45
I/O Terminals	80	-	-	40	-	80	-
UHD Tape	400	400	-	400	-	400	-
Computer Compatible Tape	100	100	47	100	47	100	47
Reader/Printer	100	60	36	100	36	100	36
Direct Access Storage	300	75	-	300	25	300	25
Mass Storage	1,600	-	-	1,600	-	1,600	-
Totals	3,180	835	128	3,140	153	3,280	153
			x 4		x 4		x 4
			512		612		612

Total Computer Associated Costs In Dollars:

Configuration A	$4,527,000
Configuration B	$3,752,000
Special Case of A	$3,892,000

6.5.3.4 Film and Reproduction Equipment Cost Estimates

In estimating the size and number of units of film equipment required for the selected configuration there are a multiplicity of parameters which could significantly affect the result, e g , temperature of film development, Chemical solution used, photographic or non-photographic quality of the output print, etc The information available to this study was not sufficient for an in-depth analysis of the influence of these parameters The approach taken was to call upon experience and judgment to arrive at reasonable first-cut estimates

There are two basic functions among the configurations for the film and reproduction equipment 1) the creation of copies from the originals received from the Data Reduction Facility for transmittal to the experimenters and 2) the duplication from archives in response to user requests for data and documents In the analysis that follows the principal assumptions were

a The loads considered are at a point in time after the first two years-when processed film etc , will have begun to be received from the experimenter and/or users

b The experimenter-and user-processed returns are assumed to equal the input rate

c Daily access to the data base is estimated to be required by 20% of the user population, accessing 5% of the base

d Since the 70mm frame film is the major load, and since only 25% of this volume is from the ES discipline, it is assumed that the film duplication load in response to user requests will be approximately evenly divided among the 5 discipline-oriented data centers which separately house the archives This assumption is in contrast to the information retrieval load (on the index and abstract file) which has been indicated to be about 80% of the total load

On the basis of these assumptions the daily loads for the initial copies to be sent to the experimenters and the duplication copies in servicing user requests are shown in Table 6 5-4 It should be noted that the preparation of the initial copies for the experimenters is shown to be performed at Central in Configuration A (Figure 6 5-3) whereas it is divided among the data centers in Configuration B (Figure 6 5-5) However, since this load is 1/10 of the duplication load in servicing user requests, it is not of prime consideration in throughput or cost estimates for either configuration - in other words it is reasonable to assume equal division among the five data centers

It is estimated that duplication speeds can be in the order of 30 meters/min (100 ft /min) for duplicating reels of film However, to maintain such speeds in frame to frame duplication, hardware modifications would be required and have been considered in the costing Similar modification will be required for the viewer/printer A single film duplicator is anticipated to be used for all film sizes In all configurations at least 2 duplicators are included in order to be able to service more than one request simultaneously In addition to the film equipment there will also be a need for a TV monitor and a video tape reproducer

On the basis of the daily loads (Table 6 5-4) equally divided among the data centers, the estimated cost breakdown is shown in (Table 6 5-5) for both configurations and the special case of Configuration A As it turns out, there is little difference in total costs between the

configurations although the co-located Central/ES Data Center shows the lowest cost The accuracy of these estimates is not considered to be as high as in the computer analysis but the figures do indicate the magnitude of the task

Table 6. 5-4. Daily Duplication Loads For All Centers Combined

	Initial Copy Creation	User Request Duplication
Hard Copy		
Film		
16mm Movie Reels	44	440
35mm Movie Reels	30	286
35mm Frames (in roll)	1,440	14,400
70mm Frames (in roll)	27,400	274,000
240mm Frames (in roll)	3,420	34,200
Video Tape	14	140

6.5.4 CONFIGURATION COMPARISONS AND CONCLUSIONS

The equipment cost breakdown for the two configurations and the special case of Configuration A have already been shown in Table 6 5-3 Comparisons on basis of computer and associated costs shows configuration A to be significantly more costly. The principal reason for this is that decentralizing the indexing, abstracting and information retrieval functions among the data centers requires a computing capacity at the ES Data Center equal to that of the Central Facility because 80% of the load is for the ES discipline However co-locating the ES center with Central virtually eliminates this cost difference. When film and reproduction equipment costs only are considered, Table 6 5-5 indicates no significant difference between the configurations Combining the figures in an overall cost table (Table 6 5-6) the same set of conclusions would be reached if cost alone is considered While the overall cost of Configuration A is more than that of B, the difference ($743,000) may be insignificant in terms of the total cost of the Space Station program, and the technical advantages of this concept For example, Configuration A is more desirable than B because it is more desirable from the viewpoint of user convenience to have all information requests serviced at one central facility Otherwise the user would have to know which discipline-oriented data center to contact Time could be lost in Configuration B for a user to go through a number of centers before locating the document he desires

The above argument in support of Configuration A is no longer necessary if the ES Data Center is co-located with the Central Cataloging Facility (special case of Configuration A) As shown in Table 6 5-6 this arrangement has the least cost It also preserves the advantage of user convenience by having a Central Cataloging Facility as well as having the same location for most of the data archives (i e , ES) Thus the overall conclusion and recommendation of the Archival Study would be to employ this special configuration

Table 6. 5-5. File and Reproduction Equipment Costs In Thousands of Dollars

Equipment	Configuration A		Confg. B	Special Case of A	
	Central	Data Center (each)	Data Center (each)	Central/ES	Data Center (each)
Film Duplicators	30	36	42	42	36
Viewer/Printers	60	65	77	65	65
B&W Film Processor	48	96	106	96	96
Color Film Processor	70	70	85	70	70
Color Paper Processor	40	80	90	80	80
Video Tape Reproducer & Monitor	100	100	100	200	100
Other	10	15	20	25	15
Totals	358	462	520	578	462
		x 5	x 5		x 4
		2,310	2,700		1,848

Total Film and Reproduction Costs in Dollars:

Configuration A	$2,668,000
Configuration B	$2,700,000
Special Case of A	$2,426,000

Table 6 5-6 Overall Equipment Cost Estimates

Configuration A		
Central Cataloging Facility	$3,538,000	
All Data Centers	3,657,000	
Configuration Cost		7,195,000
Configuration B		
All Data Centers		6,452,000
Special Case of Configuration A		
Co-Located Central/ES Center	3,858,000	
All Other Data Centers	2,460,000	
Configuration Cost		6,318,000

As indicated earlier, the recommended location for the co-located central cataloging/information retrieval facility would be at the data center which stores earth sciences data. A possibility which appears particularly attractive is the location of the co-located facility at Sioux Falls, S. D An archive is currently being implemented there to house the majority of earth sciences data obtained from the Earth Resources Technology Satellite Thus co-location at this site would bring together nearly all earth sciences data in a single location, centrally positioned within the United States

REMOTE INTEGRATION TESTING 7

7.1 INTRODUCTION

A special data handling problem results from the requirement for remote experiment integration testing In this concept, an experiment located in a ground based laboratory is functionally integrated with the Space Station while the station is in orbit This requires a type of integration facility located either at the experiment developer, or at an experiment control and/or launch facility In either of these cases, a data flow interface must be integrated and the data management elements must support the real time problems associated with the integration

The purpose of integration testing is to ensure that when elements of a system are joined together, they will function as specified without hazard and without the danger of interference in the operation of other system elements This is exceptionally important in the Space Station environment because of the great expense of delivering hardware to orbit, the difficulty of providing necessary technical skills in orbit, and the precautions necessary to the safety of the astronauts Consequently, remote integration concepts are important as means of maximizing confidence that systems will work as planned when delivered and installed in orbit

This section therefore examines several alternative means of conducting remote integration testing, their relative advantages and their peculiar problems, and estimates on a functional level their interface with the ground information management system described in previous sections

7.2 REMOTE INTEGRATION PROBLEMS

Remote integration testing has a number of problems which are independent of the approach to implementation The most severe of these problems are described below

7.2.1 LIMITATIONS

Technical limitations in remote integration testing include the following

7.2.1.1 Nonreal Environment

With the experiment on the ground, its performance may be affected by the inability to provide its true operational environment This may be alleviated by substitution or simulation to a degree dependent upon the particular experiment This must be taken into consideration in the following areas

- Man/machine interface
- Vacuum environment
- Microgravity
- Physical interface
- Presence of phenomenon

7.2.1.2 Communication Time Delay

Integration testing remotely is complicated by the long communication delays between Space Station, Tracking and Data Relay Satellite (TDRS), and the ground-housed experiment Experiments which are autonomous and essentially use the data bus only to transfer outputs, or experiments which operate at very slow rates would, of course, not be affected On the other hand, those experiments which operate under control of the central computer or other elements of the Space Station and which depend upon rapid intercommunications would present a problem

7.2.1.3 Configuration Control

The Space Station will operate over a long period of years Experiments will be integrated periodically, requiring the incorporation of designs which are years apart While the design of the experiment will be new and conform rigidly to its interface requirements, it will incorporate newest technology, while the system into which it integrates will be much older, will have gone through numerous repairs, replacements, and engineering changes, and will incorporate earlier technology With these factors, the likelihood of mismatch increases with time

7.2.1.4 Space Station Operational Time

Incorporating the Space Station in the conduct of integration testing involves dedicating Space Station operating hours to nonoperational functions Because of the high dollar value of Space Station operating time, it must be kept to a minimum for activities that do not produce direct data outputs

7.3 CANDIDATE CONCEPTS

Three alternative concepts considered for remote integration testing are shown in Figure 7 2-1, Remote Integration Testing Concepts They differ in terms of degree of testing done and the motive of communications with the Space Station during or in connection with testing

7.3.1 CONCEPT 1

In Concept 1, communications is most complex in that the experiment is directly controlled through the communications link by an experiment controller in the Space Station If the experiment is controlled by software directly, then interface is effected through the ground data bus which is tied into the Space Station data bus via the TDRS In this case, the most intimate functional electrical interface is accomplished limited by the communication time delay mentioned above Software could have been loaded into the Space Station central computer previously by way of the up data link

This concept would be most useable for experiments of varied complexity but which would not suffer from the communication time delay

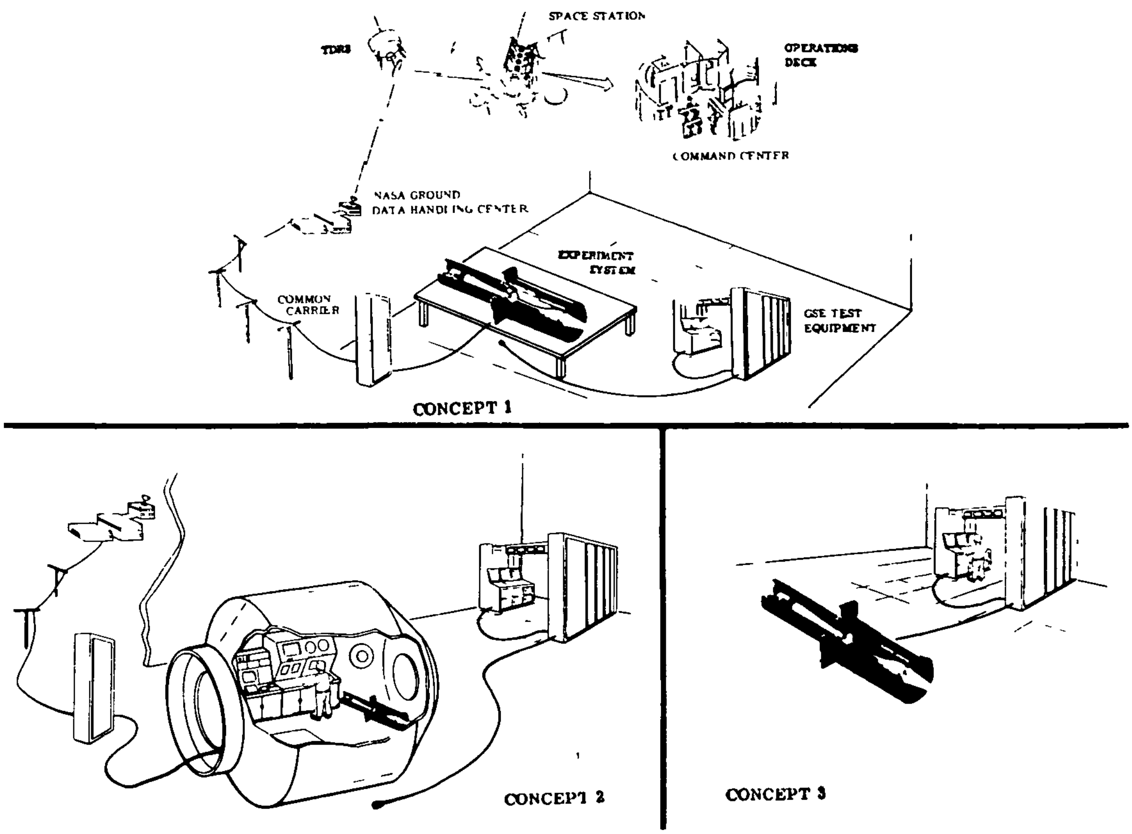


Figure 7. 2-1. Remote Integration Testing Concepts

7.3.2 CONCEPT 2

Concept 2 involves a payload module or a mockup engineered to identify with the Space Station At the additional cost required, this approach would permit a more complete integration testing in that physical, thermal, and possibly even vacuum interfaces could be tested Again, communications with the previously loaded software in the Space Station central computer is afforded through the ground data bus

In the case that the ground fixture is an actual payload module, the most effective and realistic interface obtains This corresponds to the method of operation planned in Case 534G for the return of RAM Module #2 for refurbishment, installation of new equipments, and the return to orbit as RAM Module #10 The addition of the ground data bus would permit this concept of remote integration testing to be accomplished

7.3.3 CONCEPT 3

The third concept corresponds to the traditional complete factory checkout No data bus is provided Interface assurance is provided by adherence to specification and by rigid configuration control Where software is required to interface, this is done within the Ground Support Equipment (GSE) Communications with the Space Station is effected via written instructions Because all interfaces are simulated rather than real, this approach provides the least degree of confidence of successful operation when the experiment is installed in the Space Station Its advantage is in that it involves by far the least cost

7.4 COMPARISON OF CONCEPTS

Within the scope of this task it was required to identify the key problems associated with remote integration testing and propose candidate solutions Since the basic problem is how to maximize the confidence of successful integration in the Space Station, the concepts discussed above offer basic solutions The following sections compare their effectiveness and propose an approach to a quantitative comparison

7.4.1 QUALITATIVE COMPARISON

A comparison of the four concepts is shown in Table 7 3-1, Concepts Evaluation

Table 7. 3-1. Concepts Evaluation

		CONCEPT 1		CONCEPT 2A		CONCEPT 2B		CONCEPT 3	
	Weight	Weight	Total	Weight	Total	Weight	Total	Weight	Total
Confidence Factor	100								
Hardware	30								
- Electrical	10	8	80	10	100	10	100	10	100
- Physical	10	0	0	10	100	9	90	10	100
- Thermal	10	0	0	10	100	9	90	10	100
Software	35	8	280	10	350	8	280	0	0
Man/Machine	35	10	350	10	350	10	350	0	0
Astronaut Time	90	0	0	10	900	10	900	10	900
Initial Cost	90	7	630	10	900	0	0	10	900
Station Time	70	0	0	10	700	10	700	10	700
Communication Requirements	50	10	500	0	0	5	250	0	0
Total Cost	40	2	80	8	320	0	0	10	400
TOTAL			1920	*	3820		2760		3200

*Concept only possible if the module is on the ground.

7.4.2 QUANTATIVE COMPARISON

It is beyond the scope of this study to do a quantitative comparison of remote testing concepts However, it is recognized that it is feasible to do so, and an approach is shown in the following Figure 7 3-1 The chart suggests that all significant factors can be expressed in dollars so that costs can be accumulated and compared

INITIAL COST	DOLLARS
Long Term Cost	$
Confidence Factor Limitations (Technical)	(Confidence Factor -1) x (Cost to Recover)
Operational Time	Test Time x $/hr
Potential Dangers	(Confidence Factor -1) x (Cost to Recover)

Figure 7. 3-1. Remote Testing Cost Factors

7.5 INTEGRATION TESTING LOCATION

Location of integration test facilities involves consideration of three sites for each of the concepts discussed, the Experiment Developer Facility, NASA Experiment Management Center, and Launch Site The applicability of each of these sites is shown in Figure 7 4-1, Remote Integration Testing Facility Capabilities, in terms of otherwise existing facilities and additional facility requirements

	1	2	3
Experiment Developer Facility			Final Testing to Specification and Preparation of Instructions
NASA Experiment Management Facility	Data Bus Available	Data Bus Available Requires Mockup or Payload Module Handling Facility	
Launch Site	Requires Added Data Bus Link	Requires Added Data Bus Link	

Figure 7. 4-1. Remote Integration Testing Facility Capabilities

7.6 INFORMATION MANAGEMENT SYSTEMS INTERFACE

There are two data interfaces The first collects calibration data from factory test and check-out data just prior to launch. The second is the actual interface to the mission management system to allow the distribution of testing data during the test

7.6.1 CALIBRATION DATA INTERFACE

Calibration data is required at the end of factory test and is utilized in the generation of the software to take calibration errors out of the instrument data Checkout data gathered just prior to launch has a less role in data management and is needed only in special cases to reconstruct listing of failure

7.6.2 INTEGRATION TEST DATA INTERFACE

The second information management systems interface is applicable for Concept 1 and Concept 2B Concept 1 requires a communication system that will allow a ground-based experiment to communicate with the mission management center and to the orbiting module in real time This means a two-way data interface for checkout and operation, plus a two-way voice interface to allow contact with the astronauts Concept 2A requires only the voice link between mission management and the checkout facility to allow the implementation of the operational functions from the mockup The other two concepts do not require an interface with the information management system

7.7 RECOMMENDATIONS

Concept 2A appears more favorable than the other approaches considered, showing the highest confidence/cost ratio

Concept 3 appears more favorable from a cost standpoint, but yields the lowest confidence factor

The remaining two concepts appear, by far, least cost effective

Therefore, a two concept approach is suggested. Concept 3 should be adopted whenever

- The experiment package is not complex
- Implications of failure to integrate are small
- Time is of the essence

Concept 2A should be used whenever

- The experiment package is very complex
- Implications of failure are great
- Integration can await a planned return of the Station Module
- The experiment will fly on a Sortie Mission

EXISTING FACILITIES 8

8.1 INTRODUCTION

Fundamental to the Space Station Data Flow Study was a need to assess the capabilities of the existing NASA facilities against the requirements determined in Section 2 of this report Visits were made to each of the major centers who have played a role in experiment programs to date Numerous persons were contacted, information was made available on existing systems, and plans were discussed for future expansion of existing facilities This information is summarized in subsections 8.2 through 8.9.

The utilization of this information is described in the succeeding paragraphs which explains the methodology of this portion of the study, and the results of this task which served as one input to the System Synthesis task described in Section 6

8.1.1 METHOD

A set of preprocessing functions was identified early in the program as basic to the handling of data from the Space Station These functions are shown in Figure 8 1-1 This list served as a guide in the interviews held with NASA personnel at the several sites shown in the figure The implication of the entries in this figure is that several positive factors exist which must be taken into consideration in the decision process, in addition to the quantitative data gathered on data handling capacity These factors are as follows

- Experience – insight
- Procedures
- Software
- Support facilities

The quantitative data is shown in Figure 8 1-2 This set of data, also gathered from key personnel at the NASA locations, is an expression of throughput in terms of data input, assuming the preprocessing described in Section 2.3, Preprocessing Requirements.

Figure 8 1-3 is a summary of the data handling requirements of each of the seven disciplines, as described in Section 2 and detailed in Appendix A This data was taken into account along with other inputs into the decision process

Guidelines and assumptions were decided upon before matching requirements against capabilities The chief among these are as follows

- Low cost
- Follow natural lines of responsibility
- Use effective existing methods
- Assume projected 1978 capabilities

FUNCTIONAL REQUIREMENTS \ FACILITIES	MSC	GODDARD	JPL	KSC	MSFC
DECOMMUTATE	X	X	X	X	X
PHOTO PROCESSING	X	X	X		X
PHOTO ENHANCEMENT	O		X		O
ARCHIVING	X	X	X		X
SCREEN	X	X	X		X
EDITING	X	X	X		X
MERGE	X	X	X		X
ANNOTATE	X	O	X		O
USER INTERACTION	X	X	X		O
SPECIMEN PROCESSING	X			X	
RETRIEVAL	X	X	X		O
MISSION CONTROL	X	X	X	X	
REMOTE TESTING	X		X		
REMOTE USER DISPLAY		X			
CORRELATION	X	X	X	X	X
CONVERSION	X	X	X	X	X

o DEVELOPING CAPABILITY

Figure 8 1-1 Existing Capability Summary

The capabilities of each of the several centers in terms of digital and image handling were compared with the requirements in each of the seven disciplines The results of this comparison are shown in Figure 8 1-4

The entries in this matrix are all independently derived, that is, an entry in a single block indicates the capacity of the center to handle only the data in a given discipline exclusively At this point in the analysis, KSC was assumed to devote its full capacity to shuttle and payload handling This was especially appropriate since this center does not have the background, or developed software and procedures that the other centers possess

8.1.2 RESULTS

The results of this task were supplied as an input to System Synthesis described in the next section of this report

8.2 KSC EXISTING CAPABILITY

KSC presently has three major systems for the checkout and data reduction of an Apollo launch They are the Saturn Launch Control Computer System (SLCC), which checks out all four stages of the launch vehicle and the associated launch vehicle ground support equipment To check out both the Command Service Module (CSM) and Lunar Module (LM), the

GSFC	Photo 9212 images/week rectified and calibrated errors removed 460 images/week precision processed 270,000 pictures produced/week Digital 4 x 10^9 bits/day Mission Control - Small program dedicated center	
JPL	Photo 460 images/week rectified, scaled, filtered and shaded 182 images/week enhanced and corrected Digital 1 x 10^9 bits/day Mission Control - Small program dedicated center	
MSFC	Digital 1 x 10^{10} bits/day Photo 700 images/week	
KSC	Digital 1 x 10^9 bits/day Mission Control - Flexible Specimens - Prelaunch processing	
MSC	Photo 2770 images/week Digital 1 x 10^9 Mission Control - Large, flexible, adaptable Specimens - Postlaunch processing existing capability	

Figure 8. 1-2 Data Handling Capability

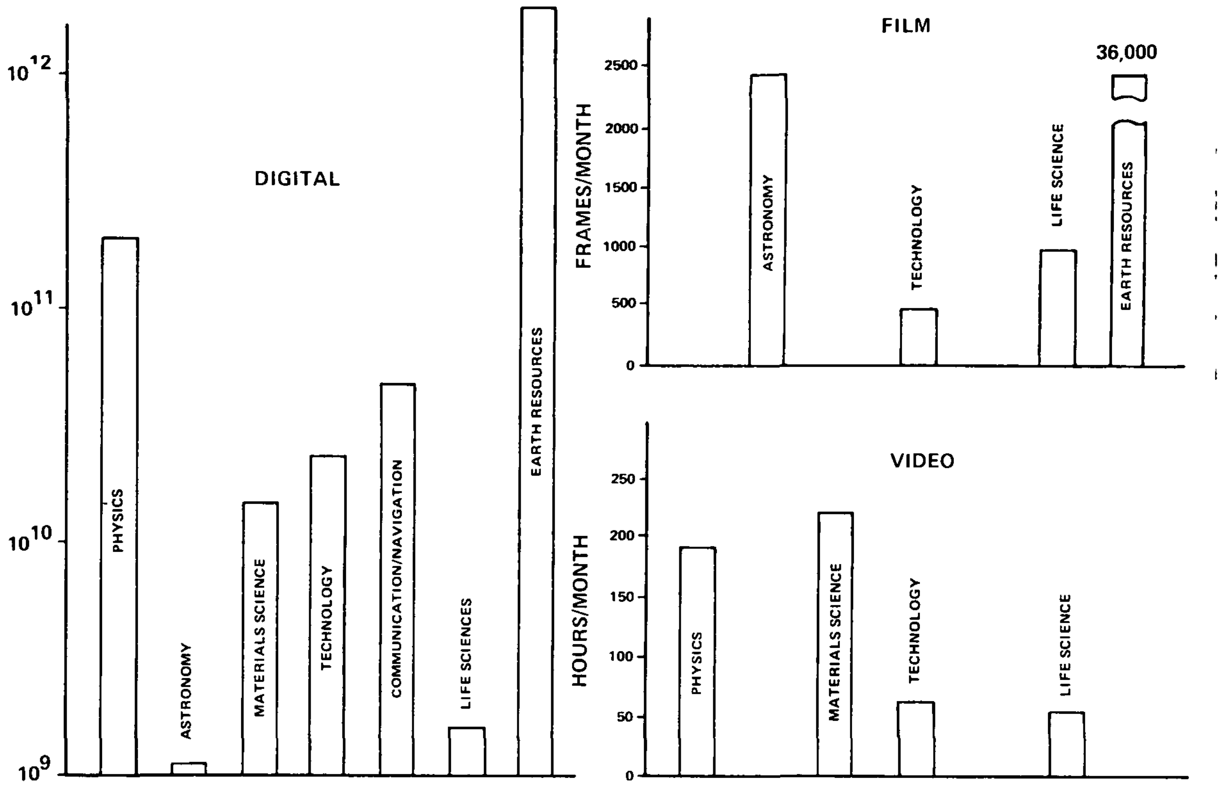


Figure 8. 1-3. Experiment Data

CENTER	DATA TYPE	DISCIPLINE: ASTRONOMY	PHYSICS	TECHNOLOGY	COMM/NAV	MS & MS	LIFE SCIENCES	EARTH RESOURCES
MSC	DIGITAL	100%	10%	66%	50%	100%	100%	2%
	IMAGE	UNDEFINED	UNDEFINED	UNDEFINED				UNDEFINED
MSFC + SLIDELL	DIGITAL	100%	100%	100%	100%	100%	100%	30%
	IMAGE	100%	100%	100%				LESS THAN 1%
GSFC	DIGITAL	100%	34%	100%	100%	100%	100%	10%
	IMAGE	100%	100%	100%				LESS THAN 1%
JPL	DIGITAL	100%	20%	33%	50%	100%	100%	2%
	IMAGE	100%	100%	100%				LESS THAN 1%

Figure 8. 1-4 Capacity of Centers to Handle Processing Requirements Projected to 1978

Acceptance Checkout Equipment (ACE-S/C) system is utilized The third system is a combination of real time and nonreal time data processing and is located in the Central Instrumentation Facility (CIF) The following paragraphs will describe each of these systems.

8.2.1 SATURN LAUNCH CONTROL COMPUTER (SLCC)

The booster checkout system consists of two RCA 110A, two SDS 930, and one DDP 224 computers One of the RCA 110A's is located in the mobile launcher, with the rest of the computers located in the Launch Control Center Basic checkout of the launch vehicle is accomplished by the RCA 110A's with the DDP 224 performing the display function The two SDS 930's are used for discrete monitoring from the launch vehicle The output is a printer which shows in real time any changes in discretes A block diagram of the total system is depicted in Figure 8 2-1

SLCC is ten years old The equipment is obsolete Spare parts are becoming a major problem in order to keep the system operational, and KSC feels that the system concept is now obsolete Therefore, they are planning to eliminate the SLCC after Skylab-A and prior to Shuttle

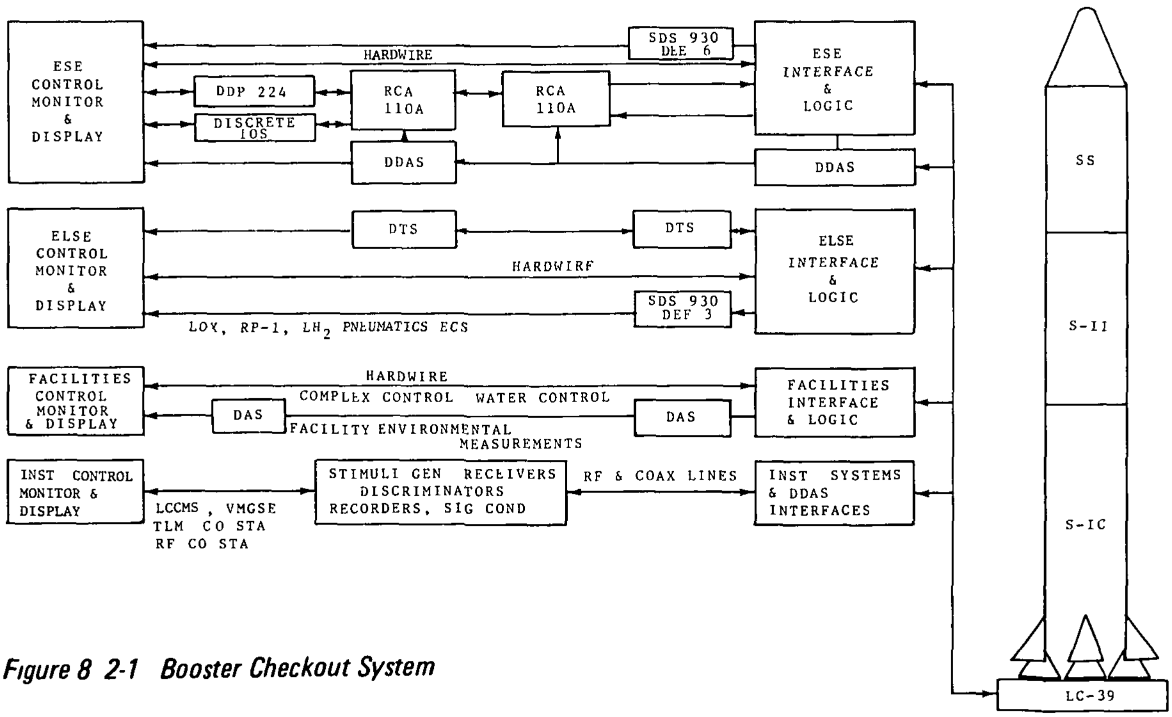


Figure 8 2-1 Booster Checkout System

8.2.2 ACCEPTANCE CHECKOUT EQUIPMENT (ACE)

The ACE system is located in the Manned Spacecraft Operations Building (MSOB) It contains two CDC 160G computers, one for uplink and one for downlink It contains a control room with displays for each subsystem and carry-on equipment to interface with

the onboard telemetry The data flow through the ACE ground station is depicted in Figure 8 2-2 The overall implemented concept including the interface between the RCA 110A's and the ACE system is depicted in Figure 8 2-3 The ACE system will also be used for checking out the Apollo Telescope Mount (ATM) on Skylab-A with certain modifications required These modifications are primarily relay functions changes to the switch selector and implementation of a 72 Kpbs link instead of the normal spacecraft 51 2 Kbps A block diagram of that system is depicted in Figure 8.2-4.

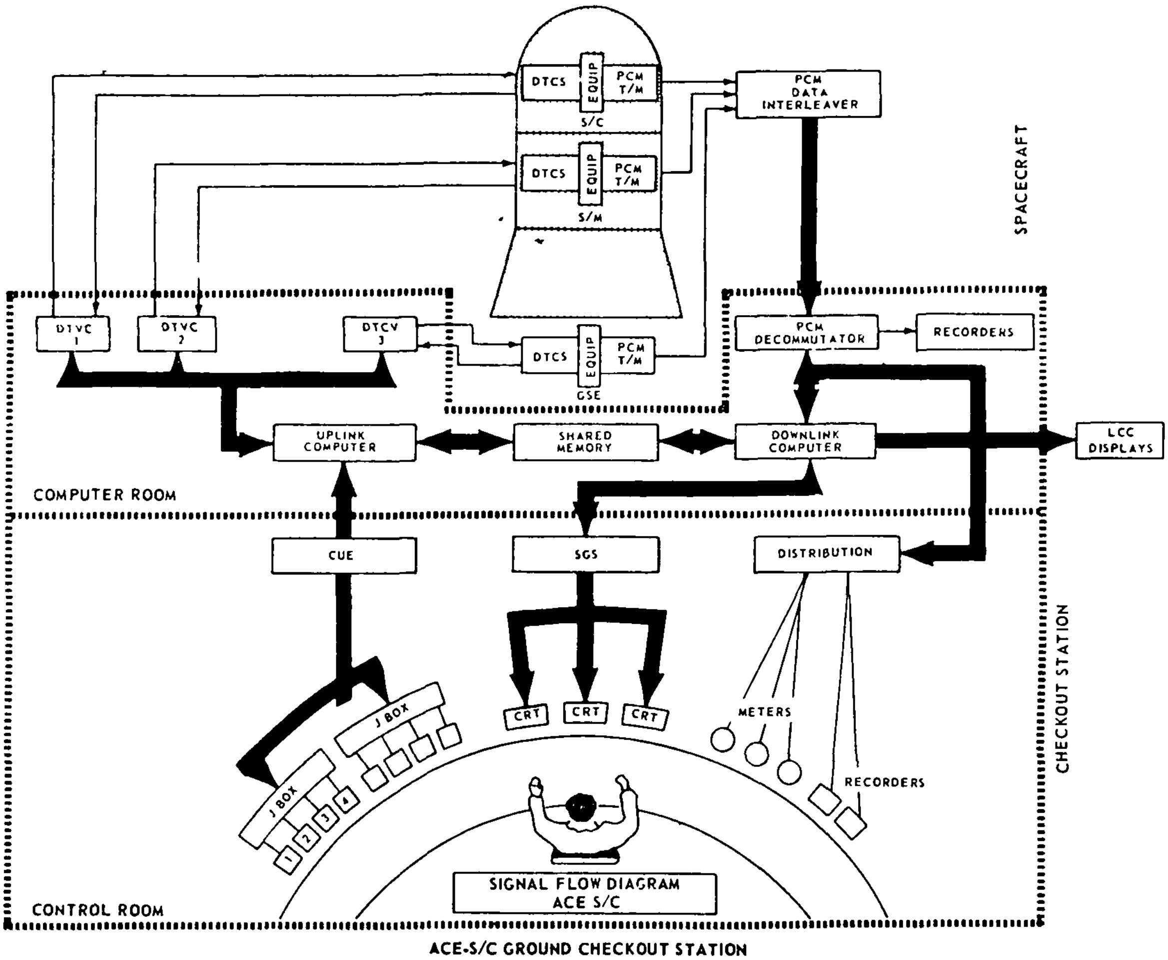


Figure 8. 2-2 Signal Flow Diagram

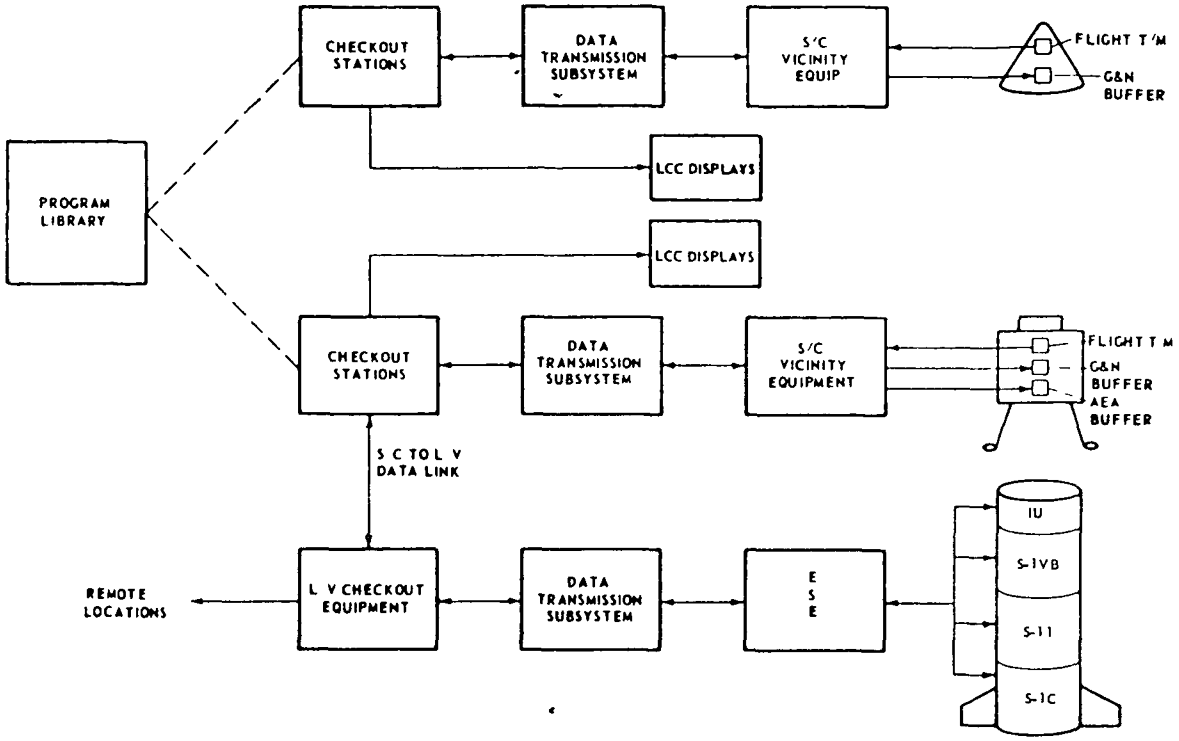


Figure 8 2-3. ACE Concept

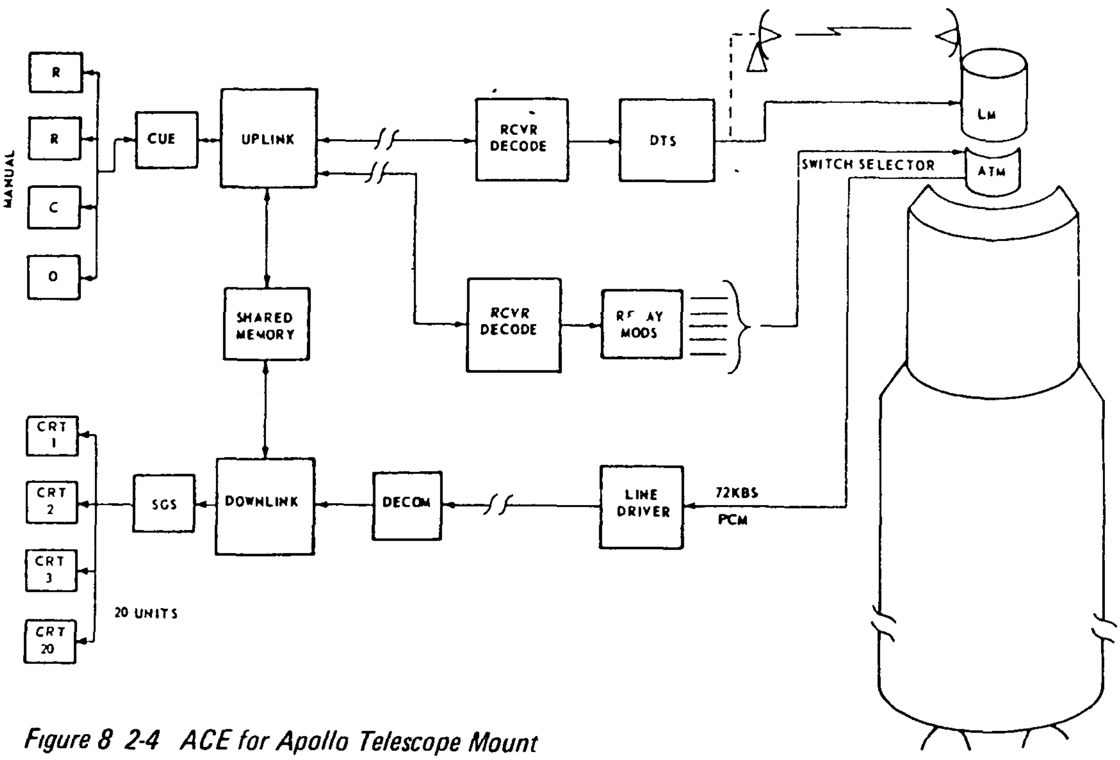


Figure 8 2-4 ACE for Apollo Telescope Mount

The ACE system was designed for modularity and flexibility, and it is KSC's plan to utilize ACE for the checkout of the Shuttle and the checkout of the experiment modules processed through KSC Figure 8 2-5 shows the locations of present ACE systems With the completion of Apollo, all of these ACE stations will be available for the checkout of the Shuttles and the experiment modules KSC plans to upgrade the computers to a third generation machine, update the displays to the latest technology, and adapt telemetry input to handle the bit rates that are presently foreseen for Shuttle and experiment modules With KSC plans in mind, these ACE systems should more than suffice for the checkout of the experiment modules through the MSOB

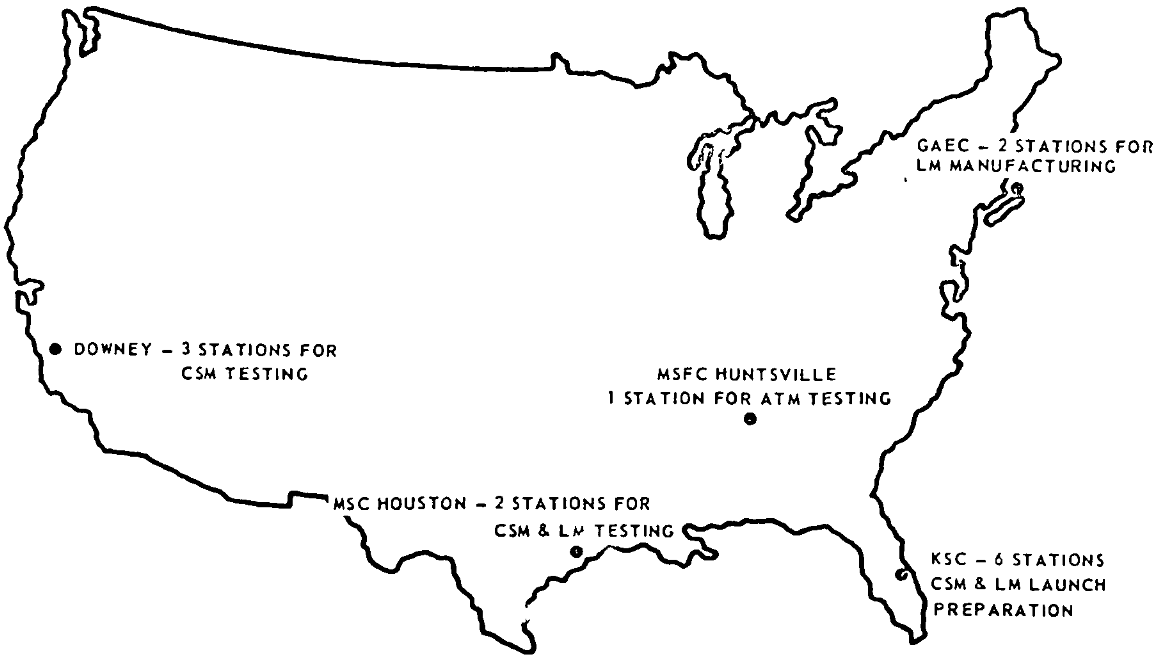


Figure 8. 2-5 ACE System Locations

8.2.3 CENTRAL INFORMATION FACILITY (CIF)

The real time data reduction and display system located within the CIF is divided into three subsystems which are depicted in Figure 8 2-6 One is the data core subsystem which accepts the telemetry inputs Second is the computer subsystem which consists of two GE 635, two SDS 930, and data interface to MSFC The SDS 930's format data to a 40 8 Kbps link for display in RTCC at MSC and the two GE 635's are used to format an output to the real time display systems for the launch control center and a control room within the CIF A more detailed block of the real time data display system is depicted in Figure 8.2-7 The detail for the data core subsystem is depicted in Figure 8 2-8 Within the total CIF system there are four data cores which can handle a variety of inputs primarily utilizing PCM or PAM at the present time There are decoders available for FM/FM also The system is flexible enough that any type of input can be adapted by supplying a data converter to meet the digital scan interface The computer subsystem configuration including its real time interface channel is depicted in Figure 8 2-9 CIF will remain primarily as described with the exception of upgrading in technology and a possible upgrading of software to allow an increase in throughput Another addition, presently being

implemented, is remote terminals throughout the KSC complex for the handling of scientific problems and data reduction. This will allow instant checkout data reduction in small quantities routed to the checkout personnel during the process rather than several days later

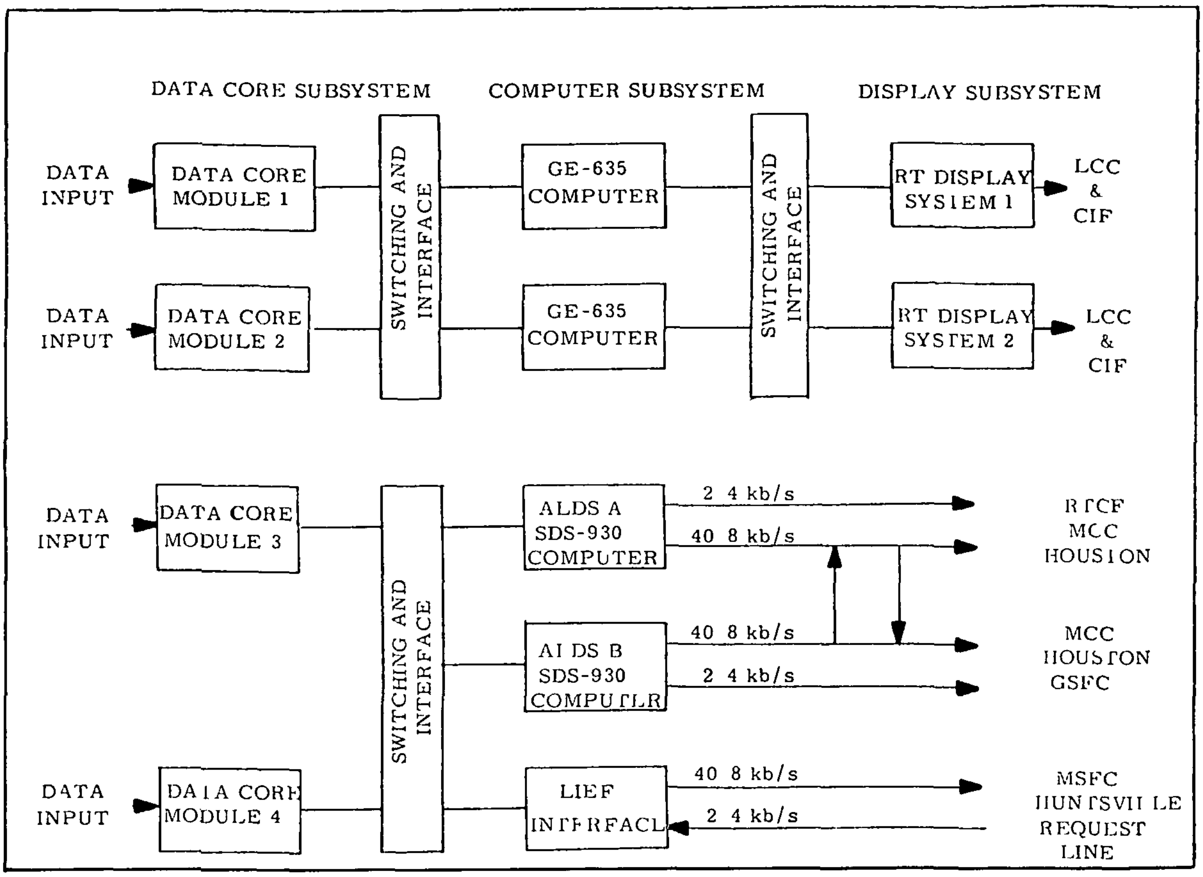


Figure 8. 2-6. Real Time System

8.3 MSC EXISTING CAPABILITY

8.3.1 APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE DATA PROCESSING (ALSEP)

The ALSEP program has three operating units on the lunar surface at this time Each unit consists of several experiments The total numer of experiments is seven (Table 8 3-1 shows the experiment utilization by ALSEP unit) Since each ALSEP package employs a 1 06 Kbps downlink, the total bit rate for ALSEP processing is 3 18 Kpbs at this time (Table 8 3-1 presents a breakdown of bits per second for each experiment) The Manned Space Flight Network (MSFN) provides 24 hour coverage of ALSEP operation by one or both of two ways The first method requires the active MSFC site to transmit to MCC the data from two of the three downlinks in real time Approximately two Kbps of data are returned to Houston for this purpose The second method consists of the site *recording data to MCC for experiment data processing The recorded data averages five* reels of 2850 meter (9,500 foot), 14 track magnetic tape per day Figure 8 3-1, a simplified diagram of this system, shows the electronic transmission of the data in the

upper part with the MSFN, Goddard Space Flight Center, and MCC interconnection and the recorded data in the lower part showing by dashed line the mail route of the recorded data to MCC Each block will be dealt with in greater detail

8.3.1.1 Real Time Processing of ALSEP Data

The ALSEP telemetry data is routed into a Univac 642B computer at the remote site This computer sorts the data into a fixed format for transmission through a Univac 494 at Goddard Space Flight Center to Houston At Houston the data is processed directly into an IBM 360/75 The 75 operates in a multi-job mode for ALSEP processing with approximately 15 percent of machine time devoted to ALSEP The balance of the computer time is used for job shop operations in the Center The data output for ALSEP is composed of standard analog chart recorders A special purpose drum recorder is used A standard high speed printer is used for the majority of the data output The system also processes a large amount of microfilm data using the Model 75 Currently it takes 7 5 hours of the 75, plus 10 hours of the microfilm equipment time to obtain 24 hours of ALSEP data on film The real time data output is primarily intended to support engineering assessment of the health of the Lunar equipment However, during the first ten to fifteen days after a new ALSEP package is located on the Moon, the principal investigators usually work in the MCC To support their activities, the real time system produces on the printer, sorted experiment data in a format readily usable by the scientists The analog chart recorders and the drum recorder are also configured to assist the experimenters

8.3.1.2 ALSEP Experiment Processing

The processing of the experiment data at MCC is accomplished in the computational facilities in Building 12 This processing center utilizes a CDC 3200 and a Univac 1108 computer plus several tape handlers and other peripheral equipment (see Figure 8 3-2)

The CDC 3200 reformats the data from the analog tapes onto digital tapes for use by the Univac 1108 The 1108 is used to produce a set of finished tapes that are sent to the principal investigators One routine used to accomplish this is a time edit routine to remove any overlapping data, since two sites can track at the same time, it is possible to have the same time segment from both sources This time edit routine is designed to remove the overlap A second routine is used to merge the several tapes created by the time edit routine into a sequential tape To provide data for the individual principal investigator, the 1108 sorts by experiment and writes a set of tapes each of which contains the time sequence data for one experiment The final routine is used to merge the data from small segments of experiment data to full reel These reels are then forwarded to the principal investigators for their use by normal mail methods Machine time to process 24 hours of one ALSEP downlink is shown in Table 8 3-2 The experiment data output from the computation center is determined by the experiment Table 8.3-3. shows the number of nine track tapes output per day per ALSEP Those tapes are forwarded to the experimenter by mail

8.3.1.3 ALSEP Data Archiving

The archival of ALSEP data is in two parts The first part is at MSC and contains the MSFN recordings, all data to date is in working storage for use in data reduction except

Table 8. 3-1 Experiment Utilization

EXP NO	NAME	MISSION APOLLO 12	APOLLO 14	APOLLO 15	DOWNLINK (bits/sec)
S031	PASSIVE SEISMIC	X	X	X	713
S034	LUNAR SURFACE MAGNETOMETER	X	X		116
S035	SOLAR WIND SPECTROMETER	X	X		67
S036	SUPRATHERMAL ION DETECTOR	X	X	X	83
S037	HEAT FLOW	X			17
S038	CHANGED PARTICLE LUNAR ENVIRONMENT			X	100
S058	COLD CATHODE ION GAUGE	X	X	X	83
--------	HOUSEKEEPING	X	X	X	17
S033	ACTIVE SEISMIC			X	10,000

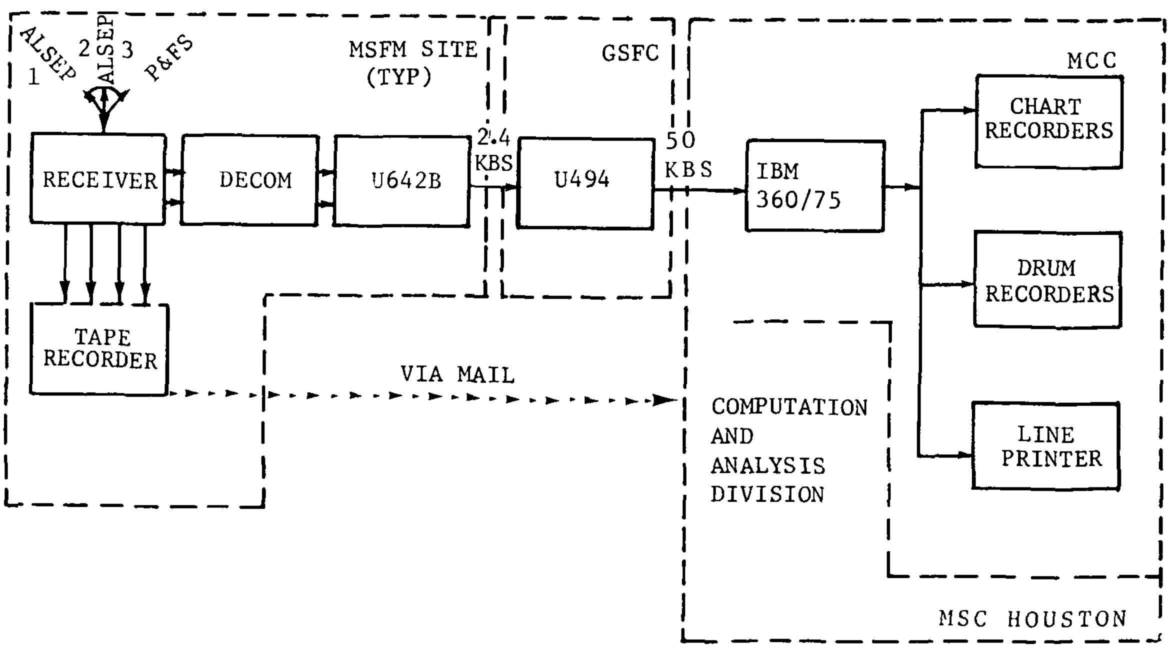


Figure 8 3-1. ALSEP Network

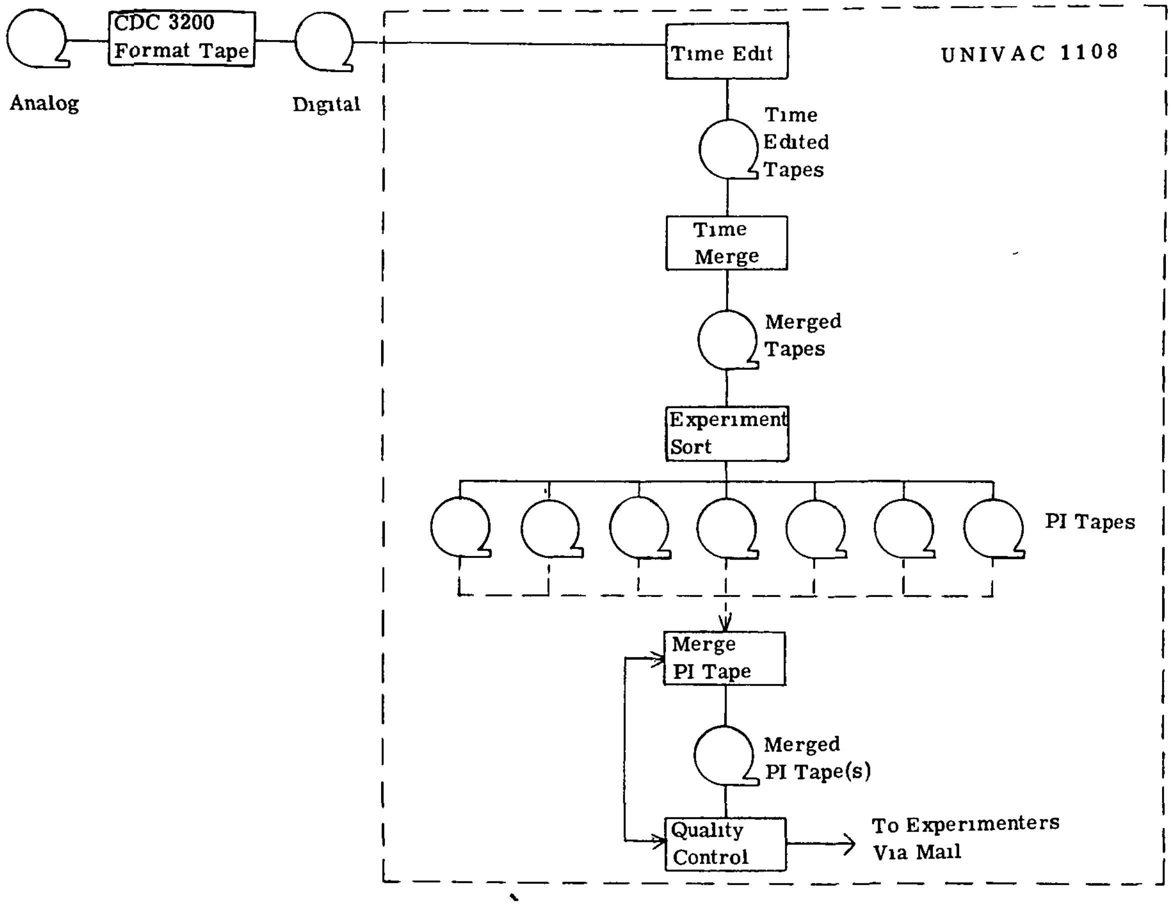


Figure 8 3-2 ALSEP Experiment Data Processing at MSC

Table 8. 3-2 Machine Time (Minutes)

STEP	CDC 3200	UNIVAC 1108
Format Digital Tape	90	--
Time Edit	--	54
Time Merge	--	12
Experiment Sort	--	24
Experiment Merge	--	35
TOTAL	90	125

Table 8. 3-3. Output Tapes by Experiment

Experiment Number	Name	Number of Days/Tape
S031	Passive Seismic	1
S035	Solar Wind Spectrometer	3
S038	Charged Particle Lunar Environment	2
S034	Lunar Surface Magnetometer	3
S036	Suprathermal ION Detector	2
----	Housekeeping	4
S037	Heat Flow	14
S058	Cold Cathode ION Gauge	30

the data from the early ALSEP I which has been put in temporary storage remote from the data reduction center at MSC It is anticipated that the entire ALSEP I only, data recordings will be forwarded to Goddard Space Flight Center for permanent storage during late 1972 This data will be approximately three years old at that time The data amount is on the order of 1,825 analog tapes per year Using the above criteria, it is assumed that ALSEP data will be retained at MCC for approximately three years before being forwarded to Goddard Space Flight Center for permanent storage

8.3.1.4 Particles and Field Subsatellite Data Processing

The Apollo Particles and Fields Subsatellite (P&FS) data is processed through the same equipment and software as Apollo Lunar Surface Experiments Package (ALSEP) data All data is downlinked at 128 bits per second and the scientific data is recorded at the remote site Real time tracking and some qualitative data is observed 3 to 4 hours per 24 hour period Also, after every 24 to 36 hour period, the subsatellite is commanded into an eight hour battery recharge cycle The data is multiplexed onboard the subsatellite, therefore, the downlink format can be varied from a pure scientific data format to all tracking or housekeeping, or a mixture of each

8.3.2 SKYLAB DATA PROCESSING

The Skylab mission employs a modified Saturn S-IVB stage as a crew living area and a scientific outpost in space This is known as the Orbital Workshop (OWS) There will be two orbital configurations One configuration will be the OWS, the Apollo Telescope Mount (ATM), the Airlock Module (AM), the Multiple Docking Adapter (MDA), and a Command Service Module (CSM) The second configuration is the same as the above without the CSM The OWS and the subsequent CSM's are launched into orbit with Saturn Launch Vehicles (SLV) The Skylab mission will consist of 26 days manned, 30 days unmanned, 56 days manned, another 30 days unmanned, and a final 56 days manned

Most of the data for Skylab will be processed via the MSFN network into Houston and will be prepared there either for real time use or nonreal time scientific investigation and data reduction The principal exception to this is the earth resources data which will be recorded

onboard and brought back by the crew when they return from the station The Skylab system employs a modification of the Apollo MSFN wherein the data will be transmitted from the site on three 7 2 kilobit circuits providing a total of 21 6 kilobit band pass in the network See Figure 8 3-3 The intention is to return to Houston all data, however this is defined as all nonredundant data, and a form of data compression is being employed to accomplish the reduction or the removal of redundant samples of any one measurement. See Figure 8 3-4

This system will process the AM, ATM, and CSM downlinks at full downlink bit rate The system will continue to use two Univac 642 B's at the remote site The Univac 642 B will compare successive iterations of each measurement, will send data to Houston only when that measurement has changed, and will not transmit the sequential redundant iterations of any measurement It will use a Univac 494 at Goddard as a communications switch to route the data from the site to Houston At Houston the data will be processed by all or part of the three 494's that are commonly called CCATS These machines will route the data to two principal users The two users are the real time system for Flight Control activity and the experiment or scientific system for the reduction of the data from the scientific viewpoint

8.3.2.1 Skylab Real Time Processing

As shown in Figure 8 3-5, the data will be routed into a 360/75 mission operational computer In the Skylab system, it is planned to maintain the Apollo configuration, employing a dynamic standby computer at least during mission critical phases The data from the 360/75 will be routed into the digital TV equipment for display The TV will be the principal method to display Skylab data for flight control There is currently no intention to use standard analog chart recorders nor is it intended to use meters There is the probability that some wide band analog recorders, and light beam oscillograph might be used, but this is still in the planning stage and would be an addition to the basic system

One of the functions of the 360/75 will be to separate, format, and route to the HOSC at Huntsville on a 50 kilobit circuit all ATM data and selected launch vehicle data for their use Hence, for flight control operations (real time monitoring of the Skylab system), one Univac 494 will be employed as a communications switch for telemetry and commanding out, and at least one 360/75 will be used both to drive the display equipment at Houston and to relay data to HOSC Huntsville

8.3.2.2 Scientific Data Processing

The second Univac 494 at Houston will route data into a 360/75 called the Mission Data Retrieval System (MDRS) The MDRS will be used to process and compile a 48 hour data base for Skylab The data base will be loaded on disc recorders, one billion bytes each These will be driven by an intermediate computer This computer has not been purchased yet, but apparently will be on the order of a 370/155 There will be a pair of these machines as well as two disc recorders The MDRS will employ the retransmission of the data from the site as its primary input During the pass, the remote site will process the downlinked data and will transmit to Houston only the nonredundant data that has been acquired by using an algorithm that detects the change between iterations of the same measurement It is planned that the system will be able to operate in a mode that will return all data that is different by

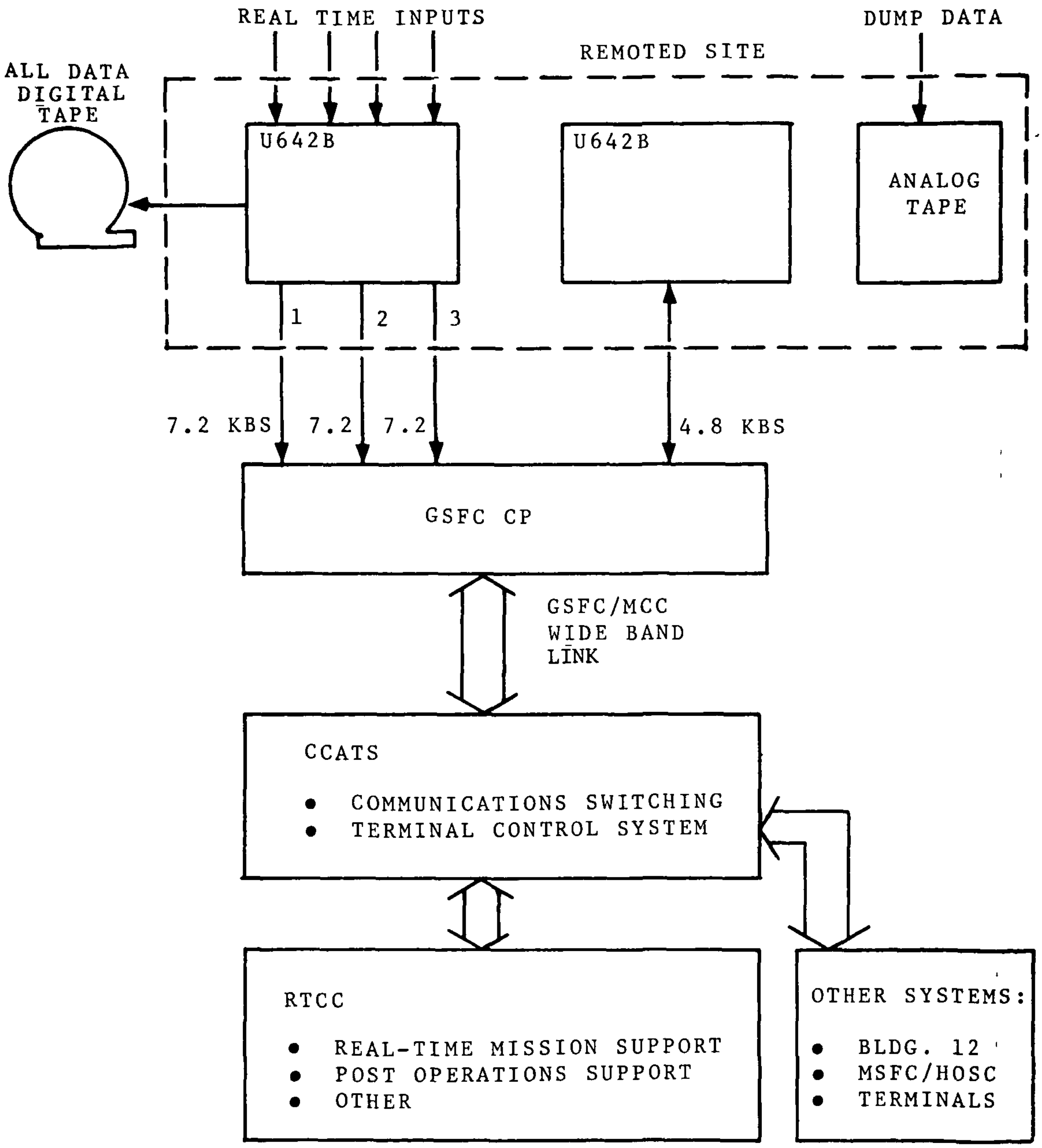


Figure 8. 3-3. Skylab Data Flow

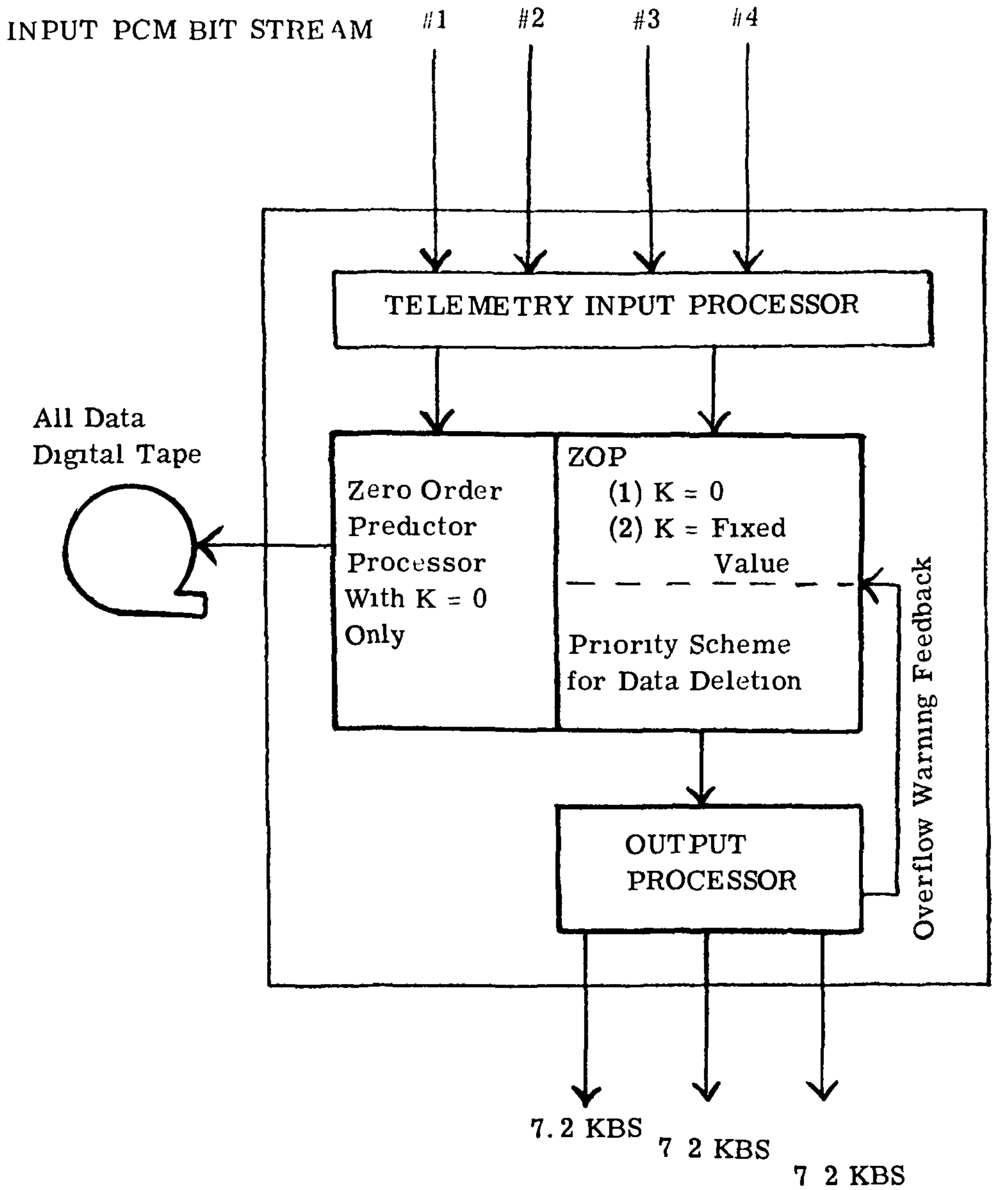


Figure 8 3-4 Skylab Remote Site Telemetry Computer Functional Processing Flow

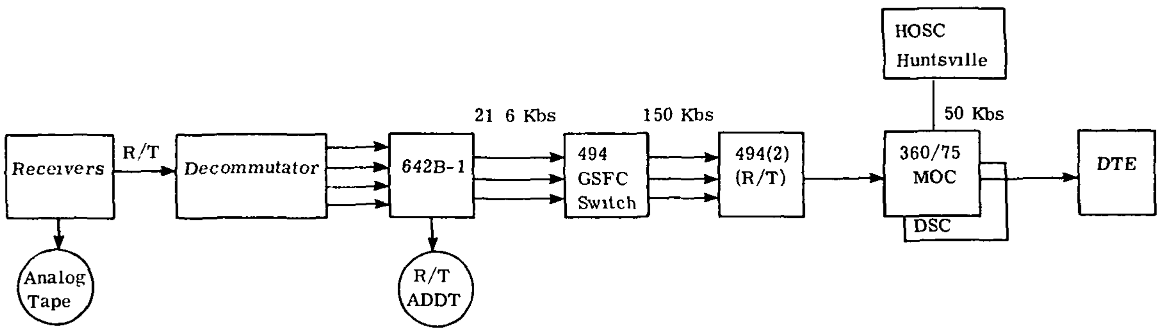


Figure 8 3-5. Skylab Real Time Processing

at least one count from the previous transmission However, under some circuit conditions it may be necessary to use a larger threshold, on the order of three or four counts, for the real time data system

At the end of the pass, the remote site will be reconfigured and will play back data from an all digital tape that has been recorded during the pass See Figure 8 3-4 and Figure 8.3-6 This is data that is always recorded with a threshold of zero in order to retain all data This data will be played back to Houston and will be routed into the MDRS Upon the completion of the first playback, the remote site will then perform a second playback. This second playback will consist of any data that has been received in dump mode from the vehicle, that is, data obtained from onboard tape recorder playback

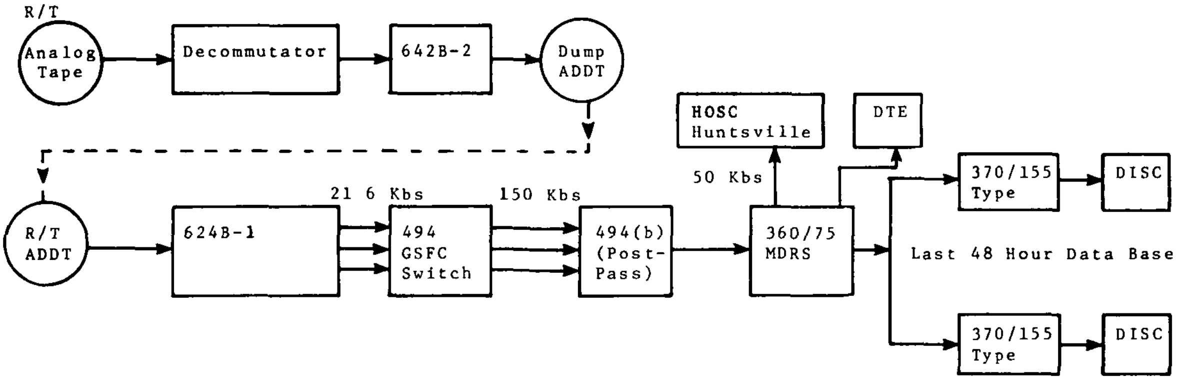


Figure 8 3-6 Skylab Post-Pass Processing

During the first ground playback, the site will have processed any vehicle dump data by playing the recorded air-to-ground tape into the second 642B which will format a tape similar to the digital tape utilized during the Skylab pass Both the real time and dump playbacks will be used to obtain the composite data for the 48 hour data base The data in the 48 hour data base will be available to the flight controllers through the digital television equipment This data will also be periodically hand carried to Building 12 at Houston where it will be played through a combination Univac 1106/1108 computer network to obtain a three to five day data base, again on large storage capability See Figure 8 3-7 The data in this three to five day data base will be employed in the reduction of the data for the scientific community The data will be output either as experiment or measurement sort data or as reprocessed data meeting some criteria from the data request that is submitted for the experiment The exact details and the quantities of data have not been totally compiled at this time although a first result has been achieved in the mission data requirements document

The 360/75 MOC will have the responsibility for sorting and transmitting vehicle data to HOSC The transmitting network will also be employed by the MDRS to transmit to HOSC, again on a 50 kilobit stream, the ATM data that is retrieved via the playbacks and MDRS equipment It is expected that this data will be forwarded to HOSC on a two or three times a day basis rather than relayed as received

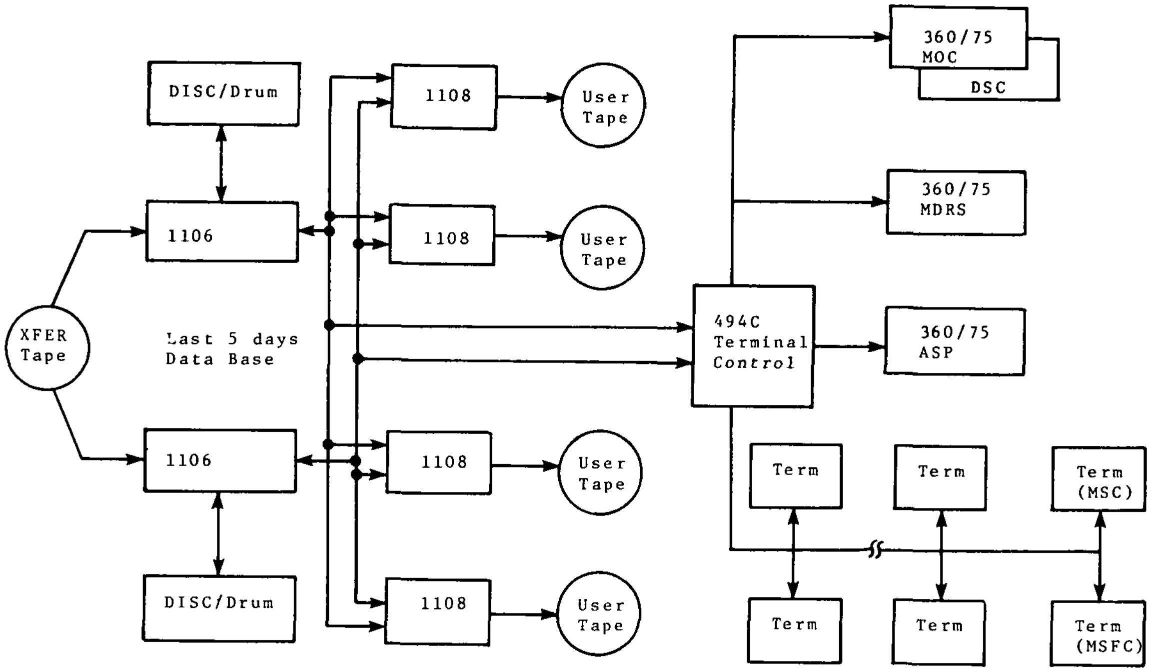


Figure 8 3-7. Skylab Experiment Processing

8.3.2.3 Skylab Earth Resources Experiment Program (EREP) Data Processing

All EREP data will be returned with the CSM, and will be in the form of magnetic tape and film EREP data handling will be performed in an off-line fashion in three phases as follows

- Phase I - Processing for Quick-Look Screening
- Phase II - Processing for Science Analysis Screening
- Phase III - Processing for Principal Investigator Requirements

Figures 8 3-8, 8 3-9, and 8 3-10 depict the data flow, handling functions, and processing times associated with the individual phases.

The ground support hardware configuration for Skylab is approximately the same as for Apollo

8.3.2.4 Mission Management Functions

Activities Scheduling Program (ASP) - The Activities Scheduling Program will be primarily a premission system although it will be and can be utilized during the mission itself Its intention is to enable the premission planning of each activity A great amount of detail is required in controlling equipment utilization and equipment placement in the orbiting vehicle The flight plan will tell the crew to remove an article from a specific location in the spacecraft and after completing utilization of it to return it to that location or some other as has been determined premission Of course, these things must be tracked in real time due to changes that

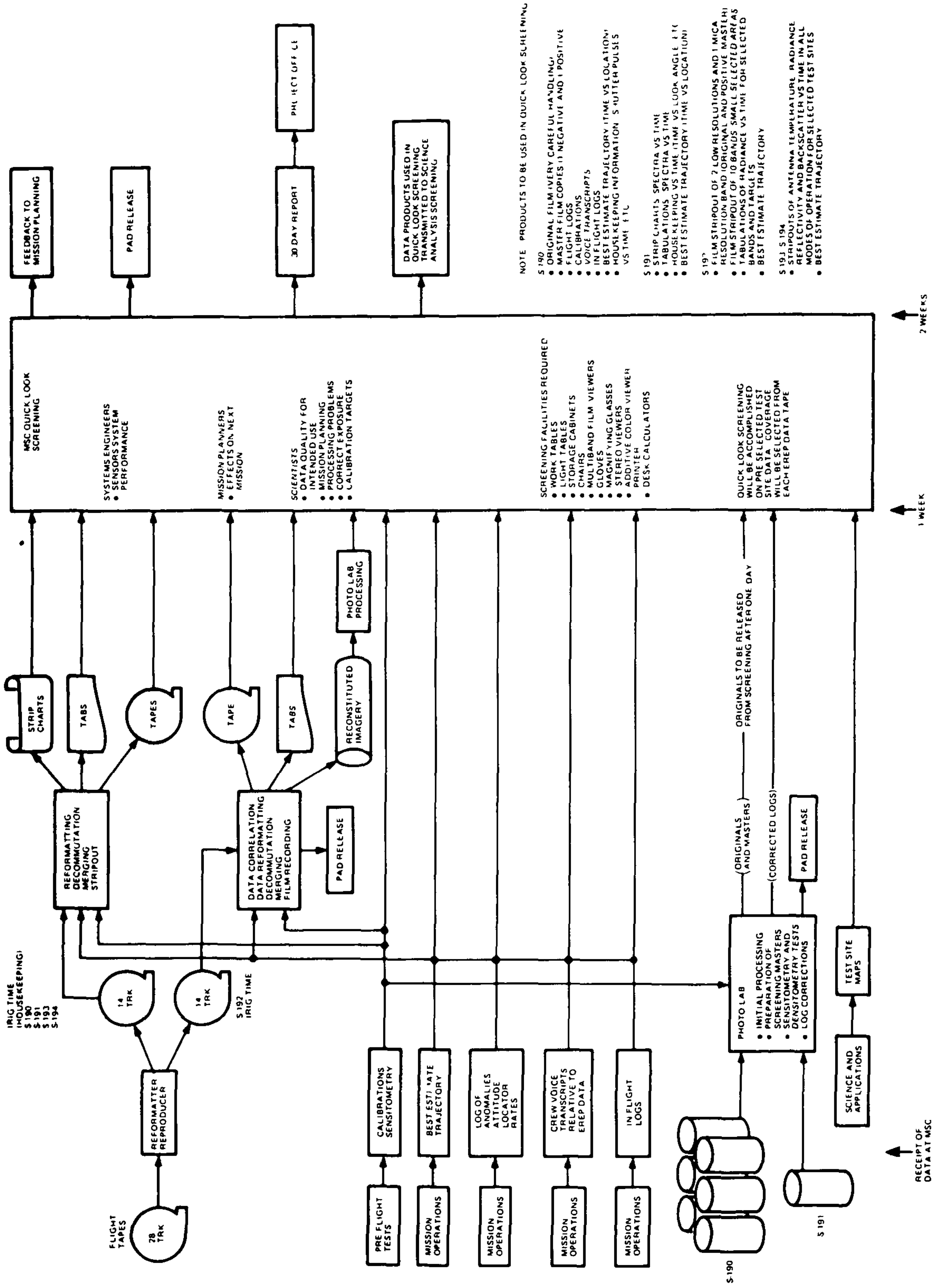


Figure 8 3-8. Skylab EREP Data Flow - Phase I Processing for Quick-Look Screening

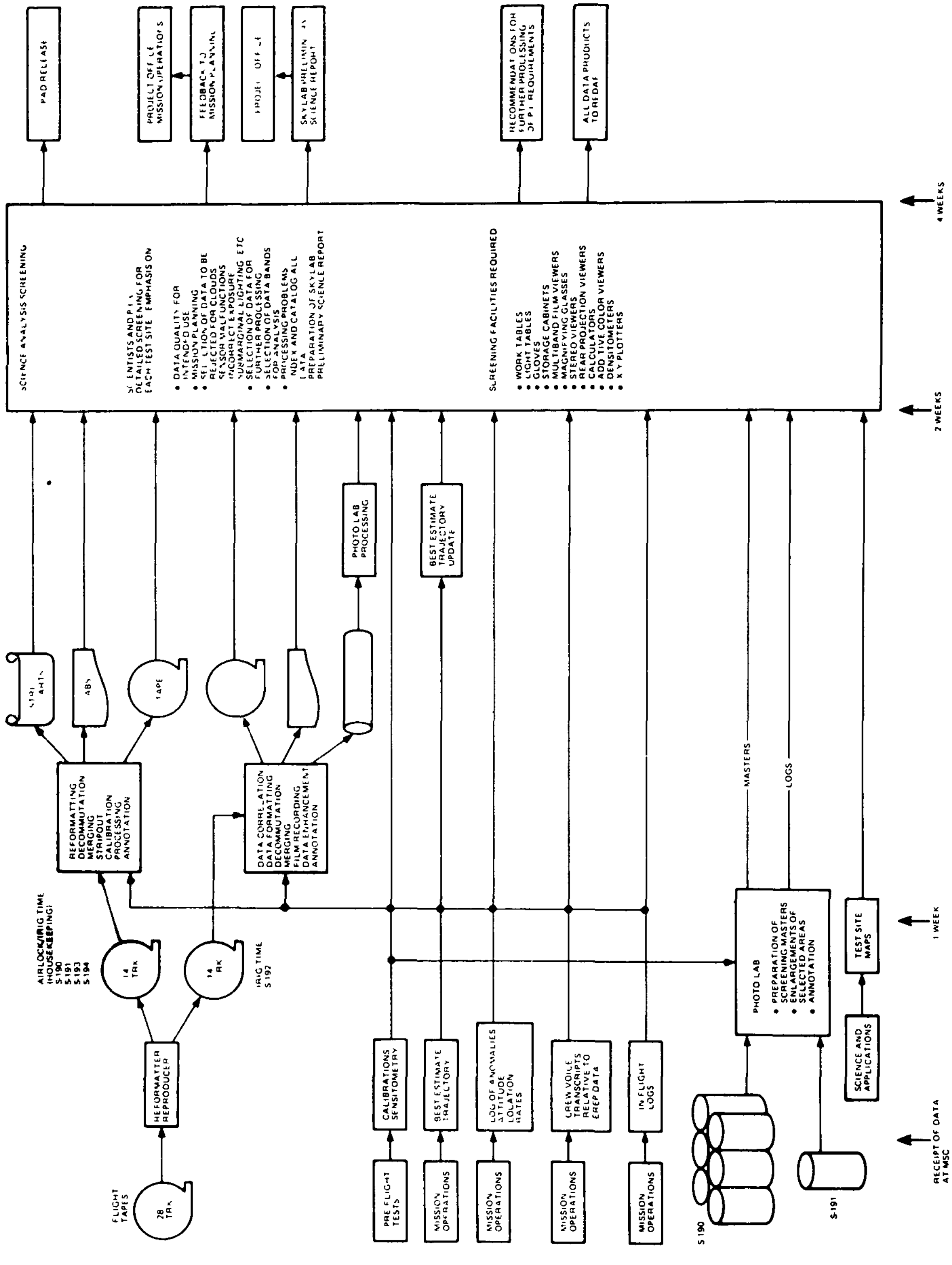


Figure 8 3-9 Skylab EREP Data Flow - Phase II Processing for Science Analysis Screening

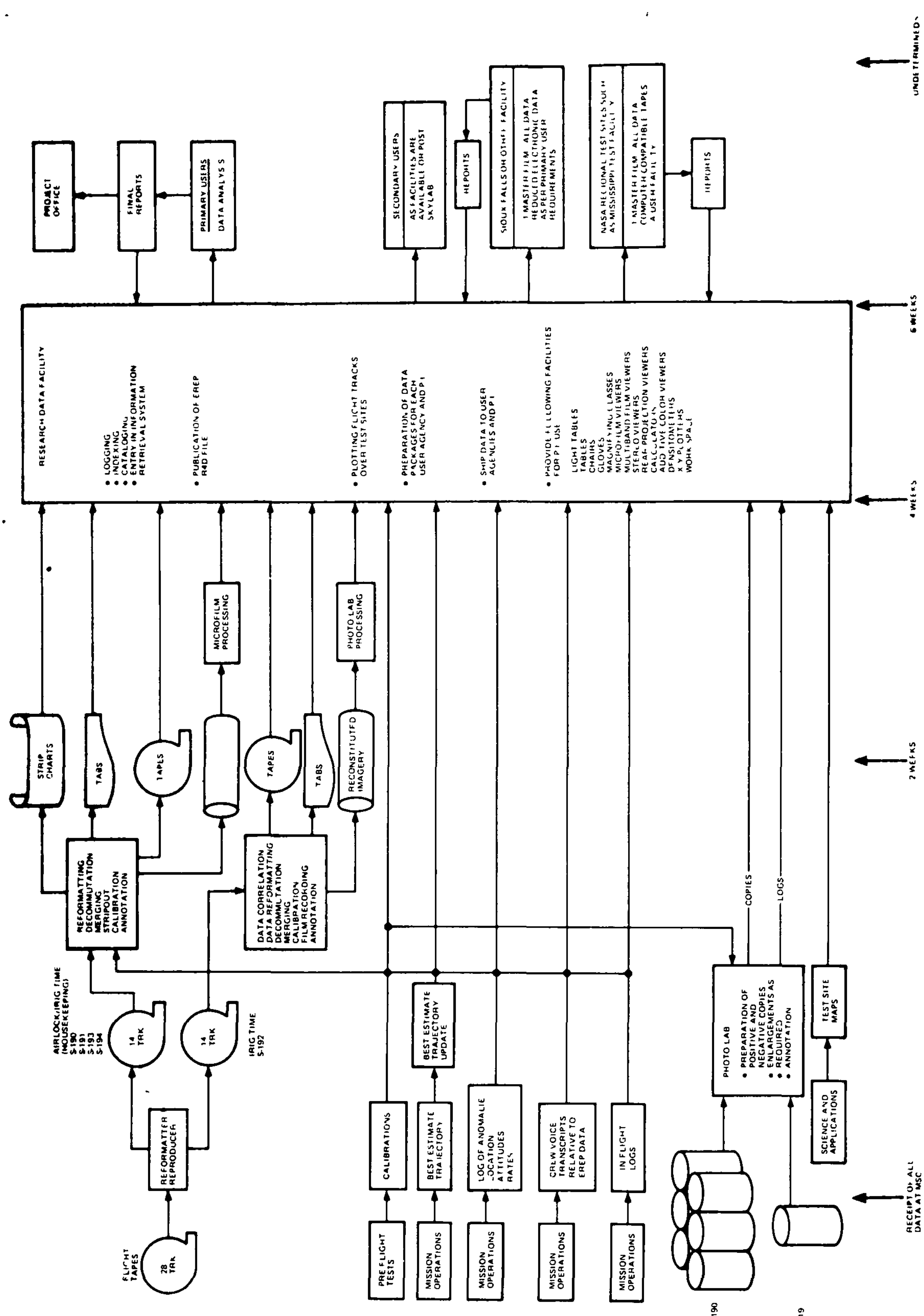


Figure 8.3-10. Skylab EREP Data Flow - Phase III
Final Data Processing for Principal Investigator Requirements

might occur and as a particular change in the flight plan comes up, the details must be worked out Therefore, the ASP will be primarily a prelaunch tool that will also be effective during the mission

Terminal System - The terminal system will interface through the third 494 This system is one that will enable the flight controller, the principal investigators, or others to access the MDRS data base to ask for particular changes in display, to change constants, or to change other values in data processing Currently terminals are projected for Houston, Huntsville, possibly the Cape, and although not in NASA's current budget or scheduling, the possibility remains for terminals to be used at various principal investigator locations to enable them to address the system also

8.3 3 EARTH RESOURCES AIRCRAFT PROGRAM

Earth resources aircraft program utilizes RB57F, NP3A, and an NC130B aircraft which fly at various altitudes and contain the major sensors necessary for earth resources These sensors are identified in Figure 8 3-11

Aircraft / Sensor Class	RB57E	NP3A	NC130B
Photographic	3 metric cameras 6 multiband cameras 1 bore sight camera	2 metric cameras 4 multiband cameras 2 bore sight cameras	2 metric cameras 6 multiband cameras 3 bore sight cameras
Infrared	1 IR scanner 1 spectrometer 1 radiometer	1 dual channel scanner 1 spectrometer 1 radiometer 1 radiation thermometer	1 IR scanner 1 multispectral scanner 1 radiation thermometer
Radar		1 side looking imaging radar 3 radar scatterometers	1 side looking imaging radar 1 radar scatterometer
Microwave		1 multifrequency radiometer 1 imaging radiometer	
Laser		1 profiler	

Figure 8.3-11 Aircraft Sensor Complements

A typical quarter of operations would accumulate approximately 36,000 frames of photometric data This includes electronic data converted into photographic frames Approximately 13 missions and 50 sights are accomplished in a given quarter, which in turn requires MSC to process approximately 2770 images per week

The function of the program is service to Government agencies, i e , Commerce, Interior, Agriculture, Navy, etc The aircraft make target runs and supply data to the users in the form of photographs and magnetic tapes All data generated from the aircraft program is archived at MSC

This service has accumulated for both Gemini and Apollo programs approximately 5,000 earth looking photographs The major data has been accumulated by the MSC aircraft program which includes data over 140 different geographical locations as shown in Figure 8 3-12, USA Test Sites In addition to the earth resources electronic and photographic data the earth resources research data facility contains more than 1,500 documents which are the results of technical investigations, programmatic studies, journal articles bibliographies and symposia proceedings relating to earth resources

The Earth Resources Aircraft Program will input underflight data as required to the EREP processing facility described in Section 8 3 2.3, Earth Resources Image Processing

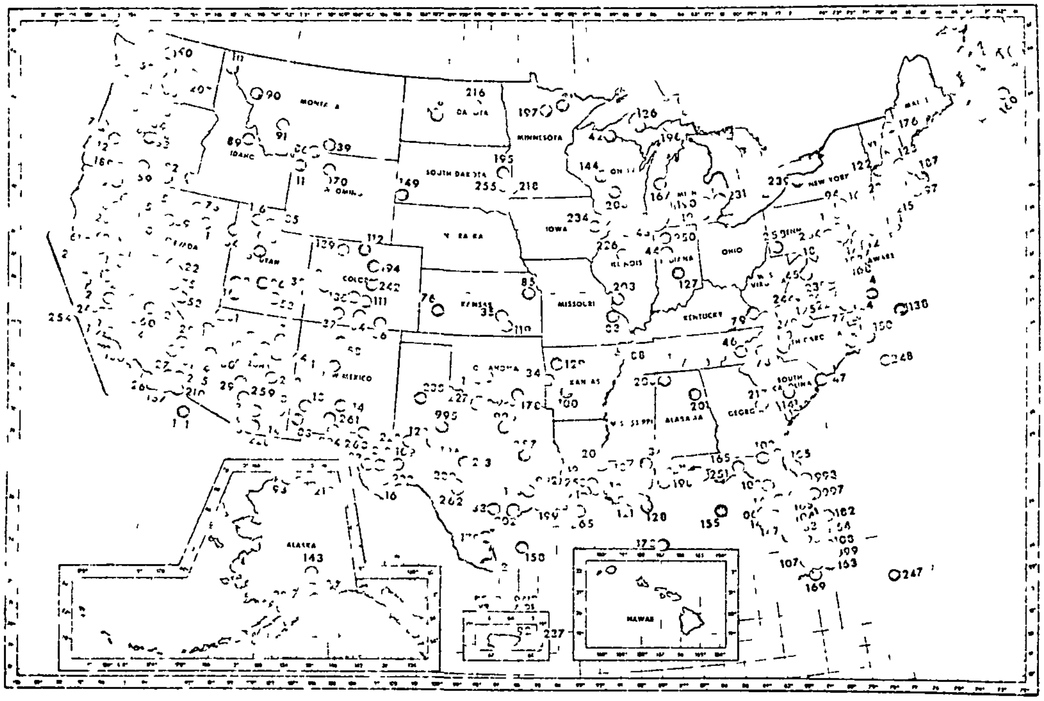


Figure 8 3-12 USA Test Sites

8.3.4 EARTH RESOURCES IMAGE PROCESSING SYSTEM (ERIPS)

8.3.4.1 ERIPS Functional Data Flow

ERIP system will be utilized on an R&D basis to do the specialized processing required for earth resources data for the 26 counties surrounding Houston ERIPS data flow, shown in Figure 8 3-13, generates three successive products the first is produced for initial screening, the second is produced for all users, and the third is produced on special request and involves a more limited number of images.

Generation of the first user products consists of a screening function and the correlation of the ancillary engineering data and the ground truth data with the image data At this point in the functional flow, tapes and photographs are generated

To determine which photographs will be utilized for the routine analysis transformations, the data is screened by the user Both hardcopy and selected tape playback are screened, using a CRT display to make determination of image quality Routine analysis includes removing light intensity variations throughout the image caused by nonlinear or imperfect instruments, removal of distortions such as centering, size, skew, tangentially symmetric and radially symmetric It further includes removal of the external errors caused by curvature of the earth This produces the second user product which is expected to satisfy the requirements of the majority of users

A further screening is accomplished to determine which images require a custom analysis This screening is accomplished on hardcopy images Custom analysis includes

- Scaling
- Enhancing
- Noise removal
- Smear removal
- Mosaicking
- Registration of two or more images
- Contouring
- Correlation of images
- Color enhancement
- Multispectral analysis
- Fourier Transform
- Integration
- Convolution
- Magnifying areas of interest
- Identifying data within boundaries

8.3.4.2 ERIPS Facility Description

The ERIPS Facilities are classified as Hybrid because of the mixture of digital and optional equipments as shown in Figure 8 3-10 Figure 8 3-14 shows the facilities required for the total ERIP system It consists of equipment located in the three buildings identified It

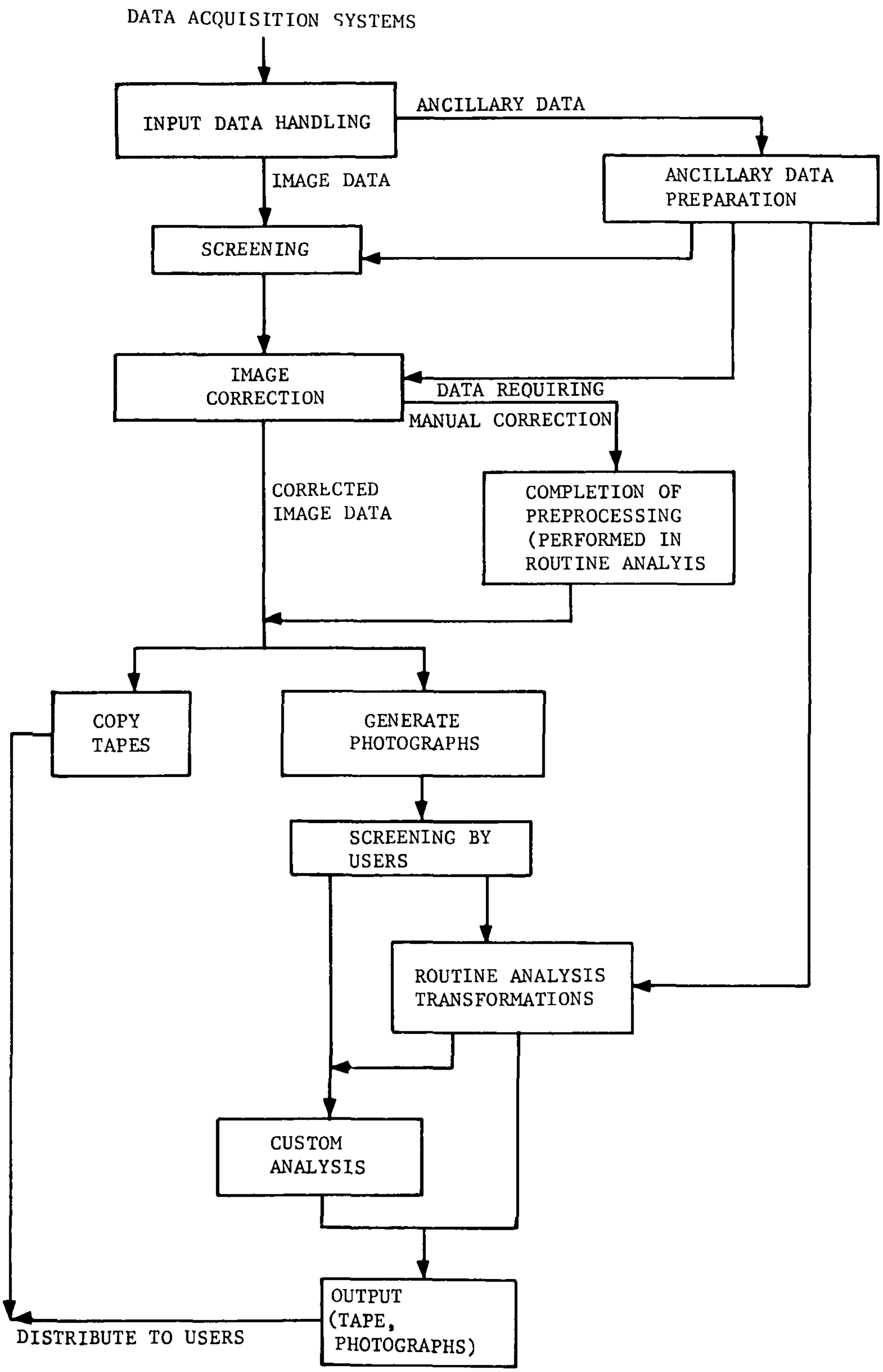


Figure 8.3-13. ERIPS Functional Data Flow

includes a data reformatter assembly (DRA) which allows for the transfer of the 24 channels of ERIP data on 28 track recorder to a 14 track recorder The passive microwave imaging system (PMIS) consists of SEL810B computer, tape recorder, teletype interface, beehive terminal interface, color television, and a film converter It performs the functions of data display and screening, transferring digital data to film or to TV and data processing for the purposes of coloration and contrast enhancement The multispectral scanner and data system (MSDS) consists of a tape recorder, teletype interface, SEL810B computer, film converter, and color television set It performs functions similar to those described for PMIS Another subsystem is the landscape interactive display which interfaces with the 360/75 and consists of a character vector generator, raster assembly memory, several refresh memories, keyboards printer, graphic display, and TV displays, including one color TV monitor The visual information processing system (VIPS) consists of a film scanner, film plotter, film converter, a data and control adapter bus, a medical display unit, and IBM System 360/44 and 1130 computers.

The ERIP system is currently being implemented

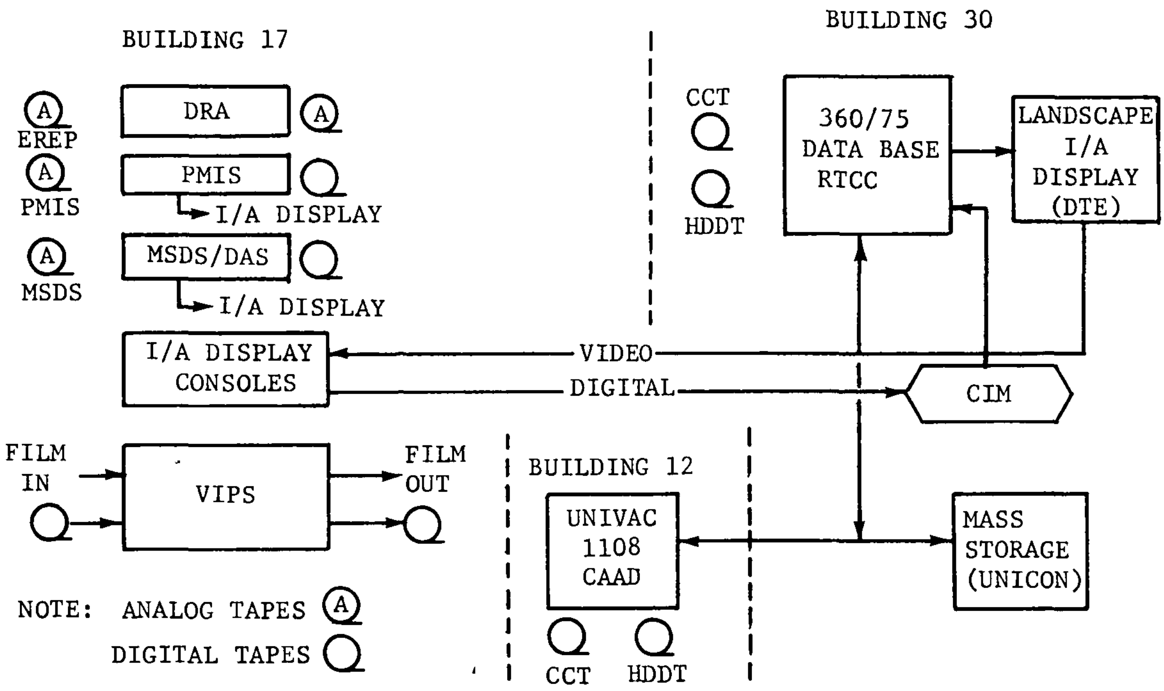


Figure 8 3-14 ERIPS Facility Description

8.3.5 FILM PROCESSING

The flow diagrams in Figures 8 3-15 through 8 3-17 show the processing sequences for the Stellar, Mapping, and Panoramic film returned on Apollo 15

Two processing teams of seven members each worked two shifts (10 hours and 18 hours) to process the entire film output within a 28 hours time span, therefore, approximately 196 man/hours of effort were required

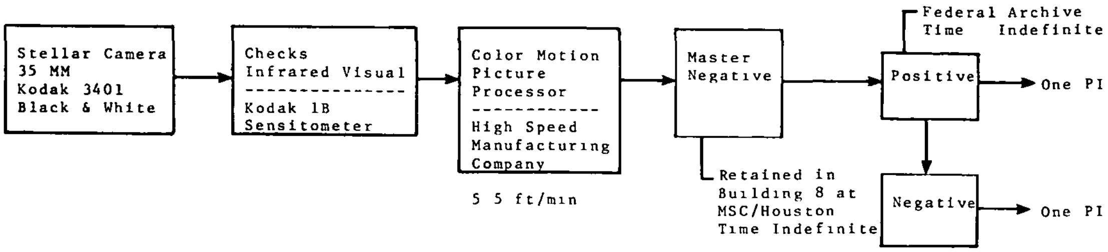


Figure 8.3-15. Stellar Film Processing

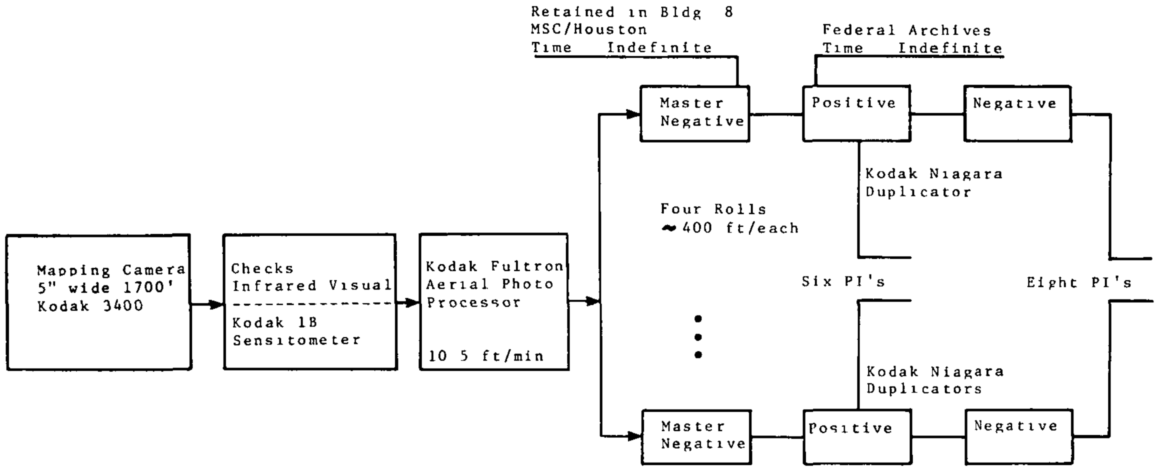


Figure 8.3-16 Mapping Film Processing

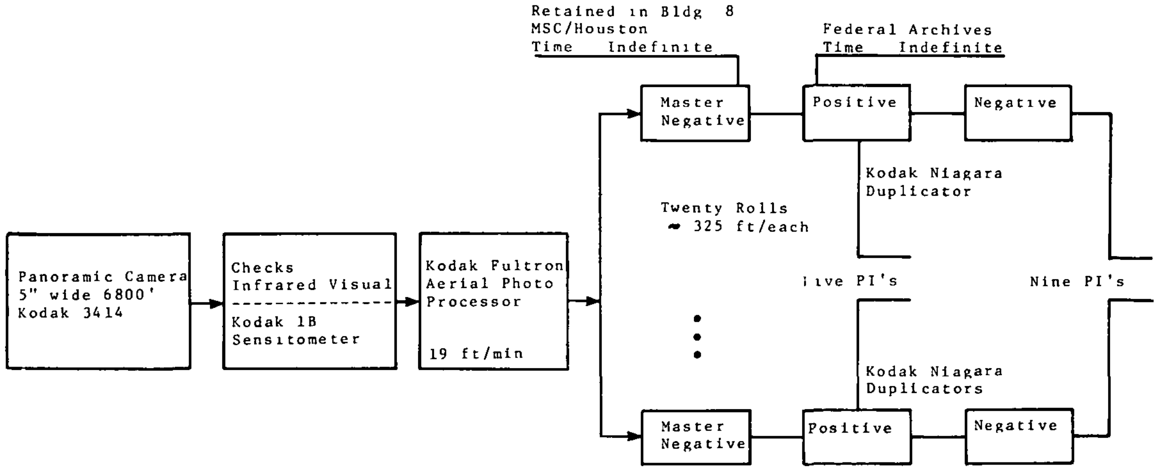


Figure 8 3-17. Panoramic Film Processing

8 3 6 BIOMEDICAL DATA PROCESSING

MSC has 14 mini-computers that are used for medical processing These machines are usually dedicated to a particular task Some typical uses are

- 1 PDP 12 used for electron microscope
- 1 PDP 12 used for radiography
- 2 Varian 620 I's used for gas chromatography
- 1 Varian 620 I used for clinical lab work
- 1 Sigma 3 for respiratory physiology, cardio vascular, and vector cardiology

The Varian 620 I uses a proprietary program for the gas chromatography Although the machines at MSC work with only one chromatograph, they are capable of operating with several in a time-sharing type of operation

The clinical lab work includes blood work and records The original design called for as many as 25 analytical units, however, the computer is now primarily a management tool with a maximum of two analytical units on line

8.4 MSFC EXISTING CAPABILITIES

MSFC has the unique capability of computer complexes at two locations with a link utilizing a 1004 between the computational facilities, therefore allowing both MSFC Computational Laboratory and Slidell to share the workload This capability gives them one of the most powerful computational centers within NASA

An additional capability existing at MSFC is the ability to process MS/MS samples as they have been doing on Apollo For Apollo they receive the samples and the associated engineering data at MSC, bring them back, split up the samples, duplicate the engineering data, and assign contractors to the task of evaluating the individual samples and generating a report To date these reports have been primarily for internal use, however, their future plans are to expand this program and generate some operational manufacturing processes in space

8.5 GODDARD SPACE FLIGHT CENTER (GSFC) EXISTING CAPABILITIES

GSFC has four primary functions which were considered in connection with this study

- Preprocessing for users
- Dedicated mission control for several ongoing programs
- ERTS image processing system
- National Space Science Data Center

They are discussed in the following subsections

8.5.1 PREPROCESSING FOR USERS

The GSFC production facility processes approximately 10,000 to 11,000 input tapes per month, and for every one input tape the system delivers four to five tapes It operates seven days a week, twenty four hours a day, and has the capacity for a bit throughput of 4 x 10^9 per day. It is presently throughputting 3 x 10^9 per day A mass storage unit is being implemented into the production processing system that will have the capability of holding 10^{12} bits Throughput today varies between four and five weeks from receipt of a data tape to the output for the scientist When the upgrading of the operation with the mass storage unit is completed, the production system will cut this throughput down to three to eight days depending on correlation requirements However, GSFC gives special service when requested with a throughput of approximately twenty four hours if there are not too many of these requests The system utilized for the production runs is shown in Figure 8 5-1 Figure 8 5-2 shows in more detail the computation system which handles data coming in from the satellite data collection network The Experiment Data Processing System is also used to handle data entering the control center described in the next section.

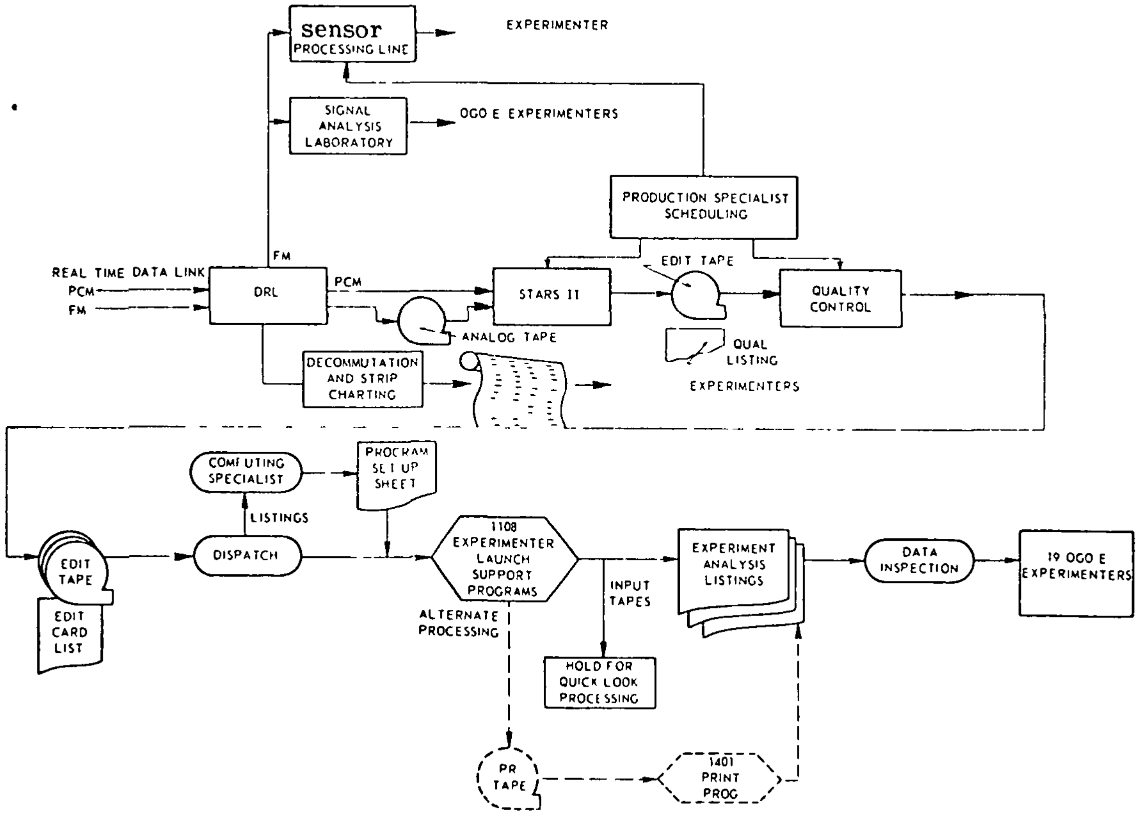


Figure 8.5-1 Experiment Data Processing System

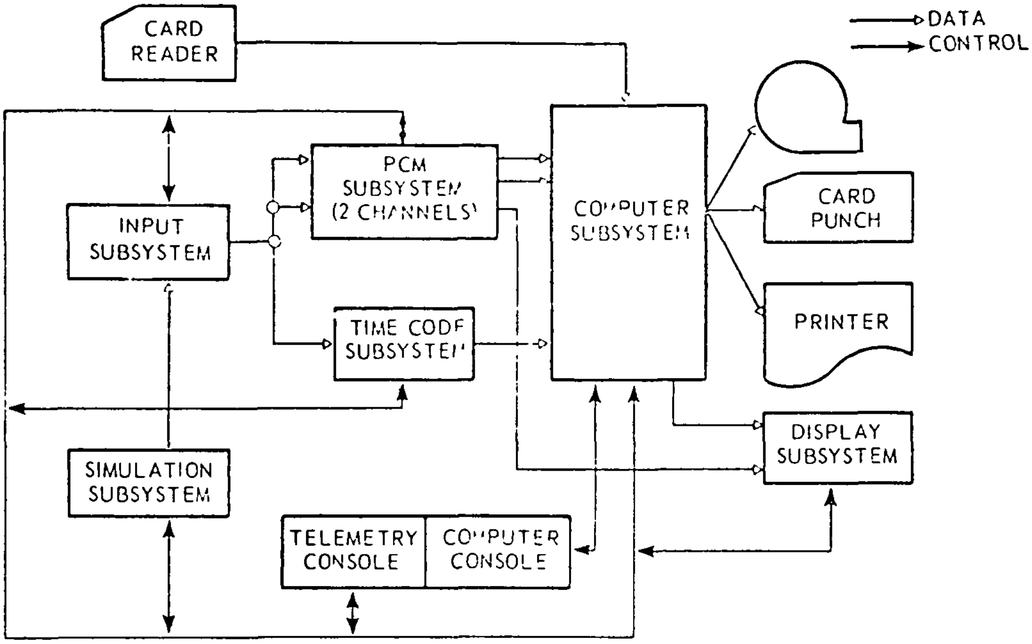


Figure 8.5-2. STARS II

8.5.2 DEDICATED MISSION CONTROL

Figure 8 5-3 shows a typical control center operation and processing for one of the many unmanned GSFC programs The one shown was developed for use with the Goddard Experiment Program.

Key features of the system are

- It is distributed among several buildings
- The OAO Operations Control Center is a dedicated facility containing an XDS-930 Computer System with
  - Tape transports
  - Printer
  - Analog-to-digital tape converter
  - Input terminal
- The GEP Operations Center provides the work area for the PI and team to interact with the orbital experiment Special output products are made available to the experiments in the form of computer printouts, CRT spectral display, polaroid photos of spectral display and microfilm The computer is not in this work area and is shared with other users

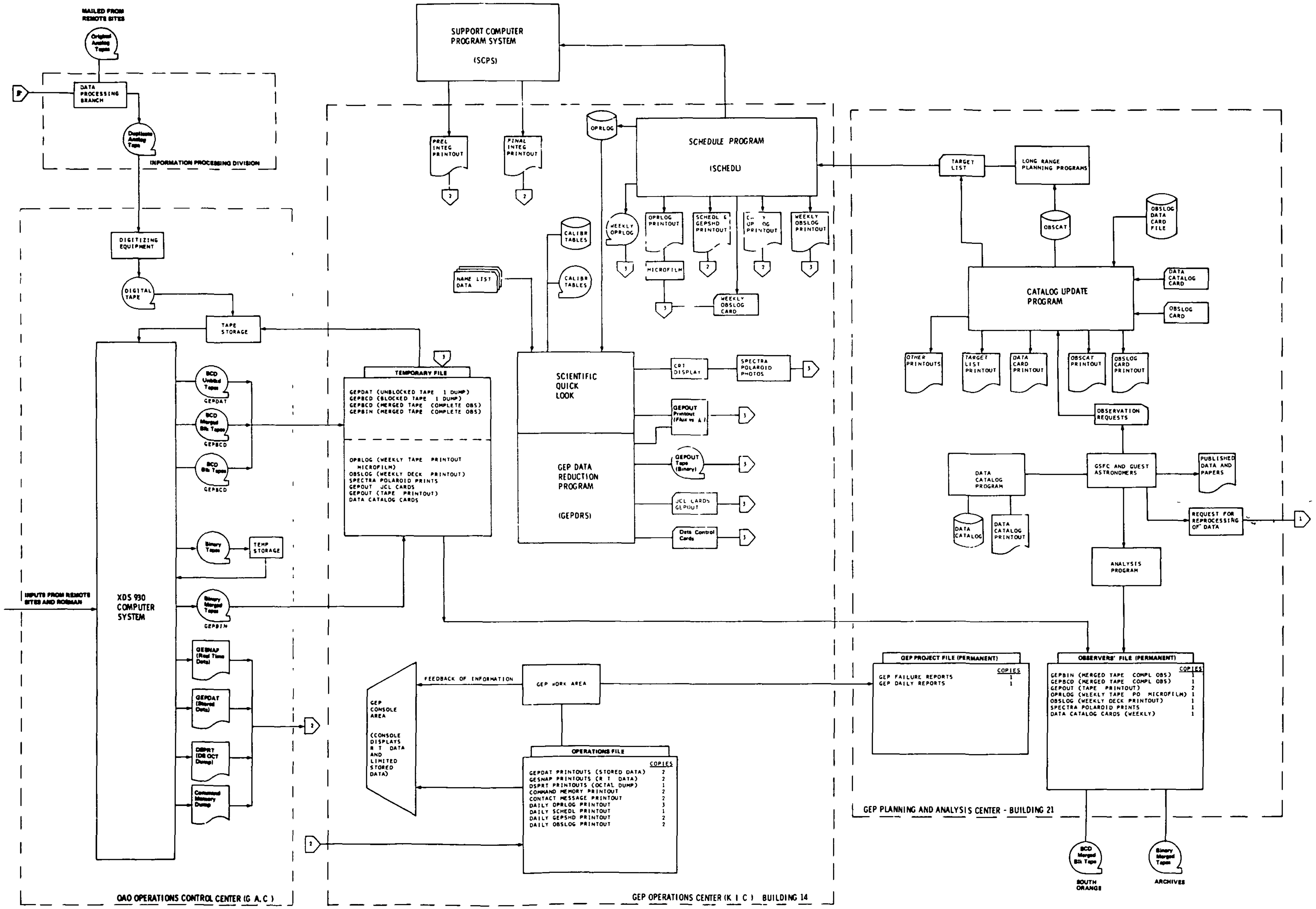


Figure 8.5-3. OAO Operations

- The GEP Planning and Analysis Center provides the nonreal time work area for mission planning functions and detailed analysis of experiment data.

8.5.3 ERTS IMAGE PROCESSING SYSTEM

The Earth Resources Technology Satellite (ERTS) facility was designed primarily to take geometric and calibration errors out of the raw data ERTS generates 1316 scenes per week The RBV has three images per scene and the multispectral scanner has four images per scene, which means the ERTS ground data handling system processes approximately 9,212 images per week. Its output is 24 cm (9 5 inches) black and white negative, 24 cm (9 5 inches) positive, and 24 cm (9 5 inches) print

For planning purposes it is assumed that there are ten investigators wanting one of each, which means for each image GSFC will generate 30 outputs GSFC, upon request, will also generate a digital tape output which will consist of about 16 x 10^6 bytes per image, a byte being defined as 8 bits In addition, 5 percent of the 9212 images can receive precision processing Precision processing is defined as correcting the image with ground control points that are being defined by NSGS There will be no enhancement or other special processes performed on the image within the ERTS facility

GSFC will only service the prime users, who are identified contractors and government agencies GSFC will catalog the images by time, place, latitude and longitude, and will annotate the images with correlation data The secondary users will be served by either Sioux Falls or Suitland Sioux Falls for Terrestrial Data and Suitland for Oceanography and Atmospheric Data.

8.5.4 NATIONAL SPACE SCIENCE DATA CENTER

The National Space Science Data Center (NSSDS) is located at Goddard and is the key archiving center for space science data Figures 8 5-4 and 8 5-5 depict the space science data flow and show how the data gets from the orbiting spacecraft to the NSSDC Figure 8 5-6 depicts the activities of NSSDC Figure 8 5-7 shows the data on hand versus the number of successful experiments Figure 8 5-8 indicates the type and number of personnel required to handle a major archiving system such as NSSDC.

8.6 LEWIS RESEARCH CENTER

Lewis Research Center is presently developing a catalog system for earth resources It is called NASIS, meaning the NASA Aerospace Safety Information System It is an interactive generalized data base management system containing the following capabilities

- Interactive search
- Alpha numeric display
- Dial-up capability
- Geographic search
- Five simultaneous terminal capacity
- Forty to fifty on line terminal capacity
- Expandability

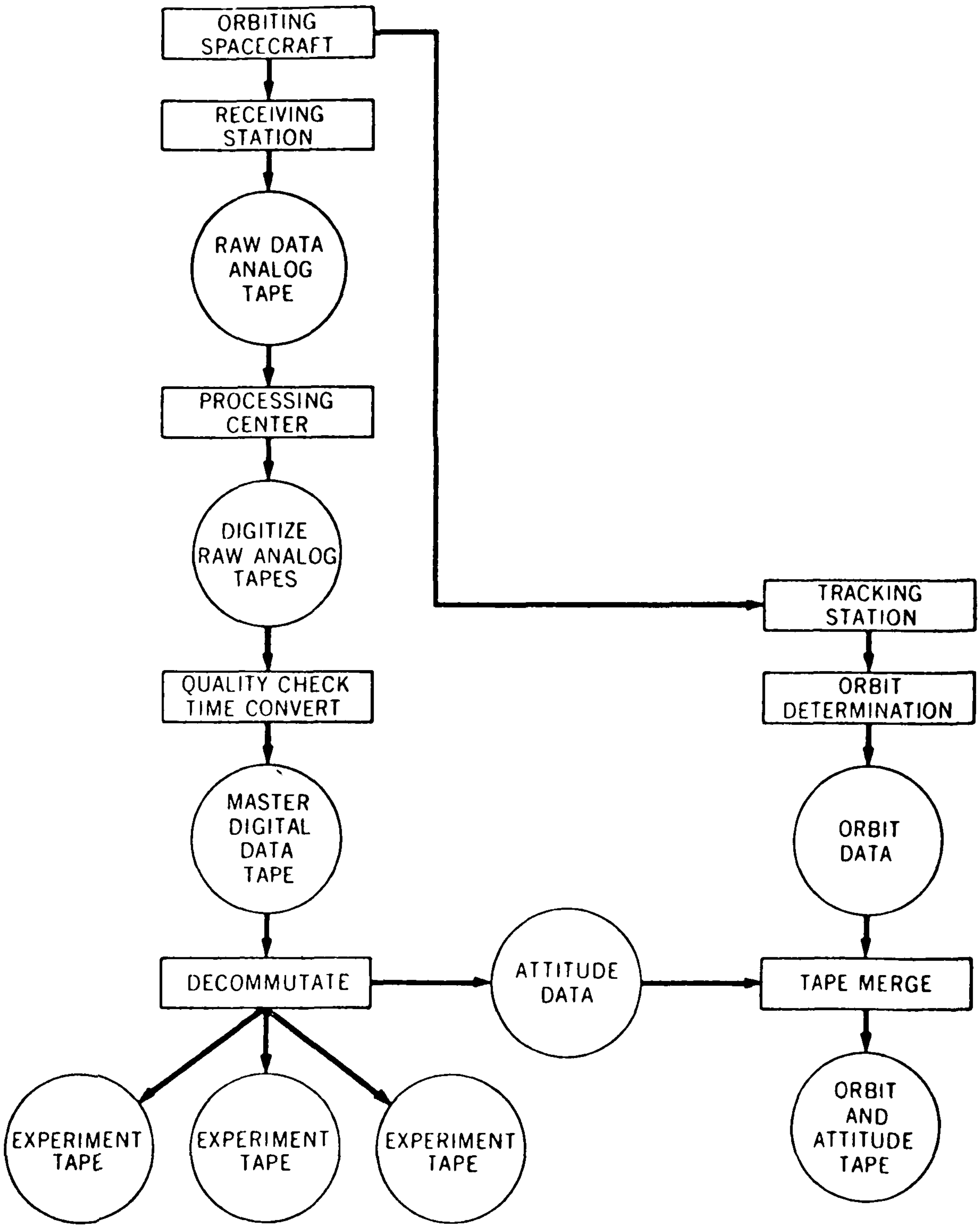


Figure 8.5-4. Diagram of Satellite Data Flow From Orbiting Spacecraft Through Central Processing Facilities

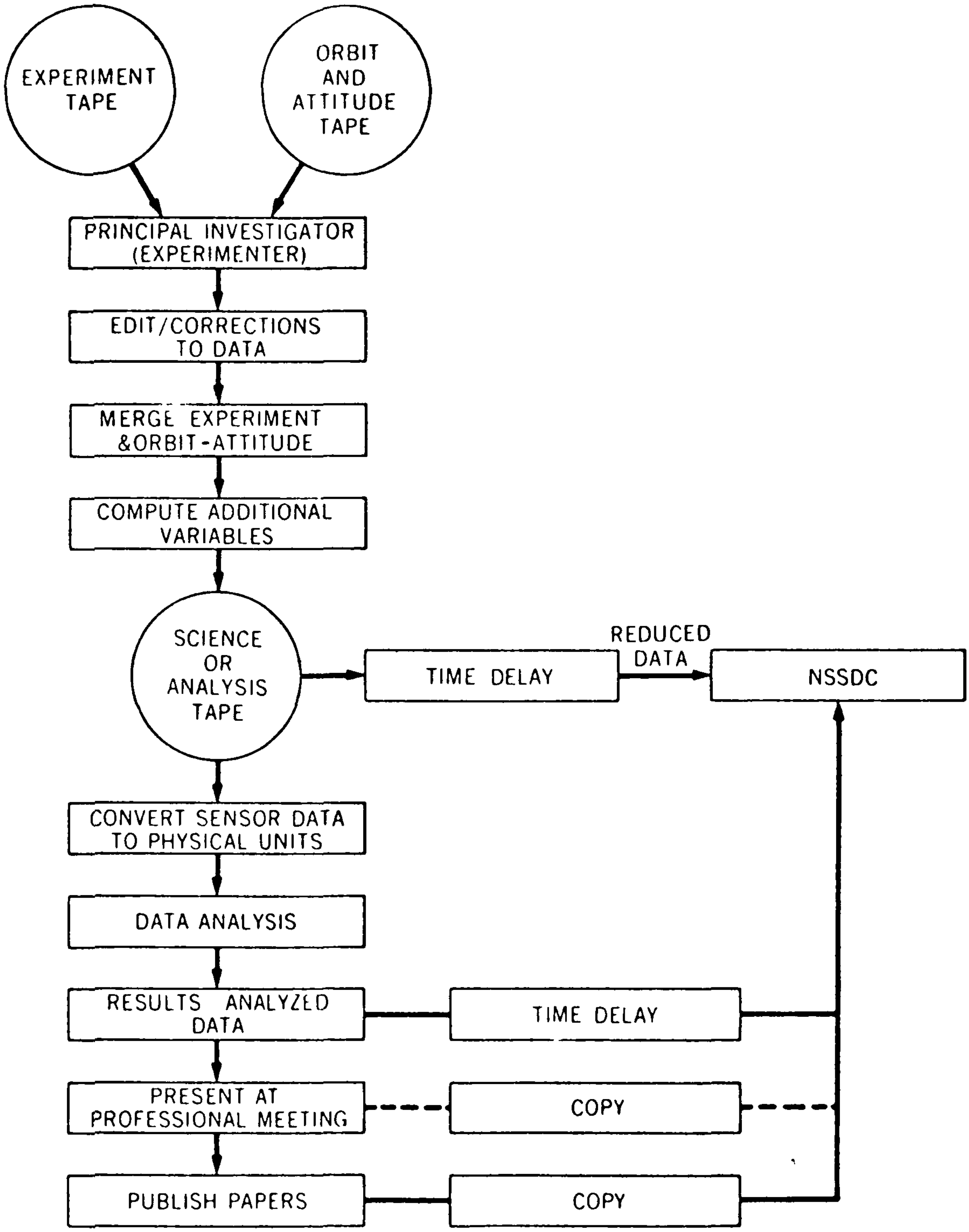


Figure 8 5-5. Diagram of Satellite Data Flow From Experimenter Through Analysis to Final Publication

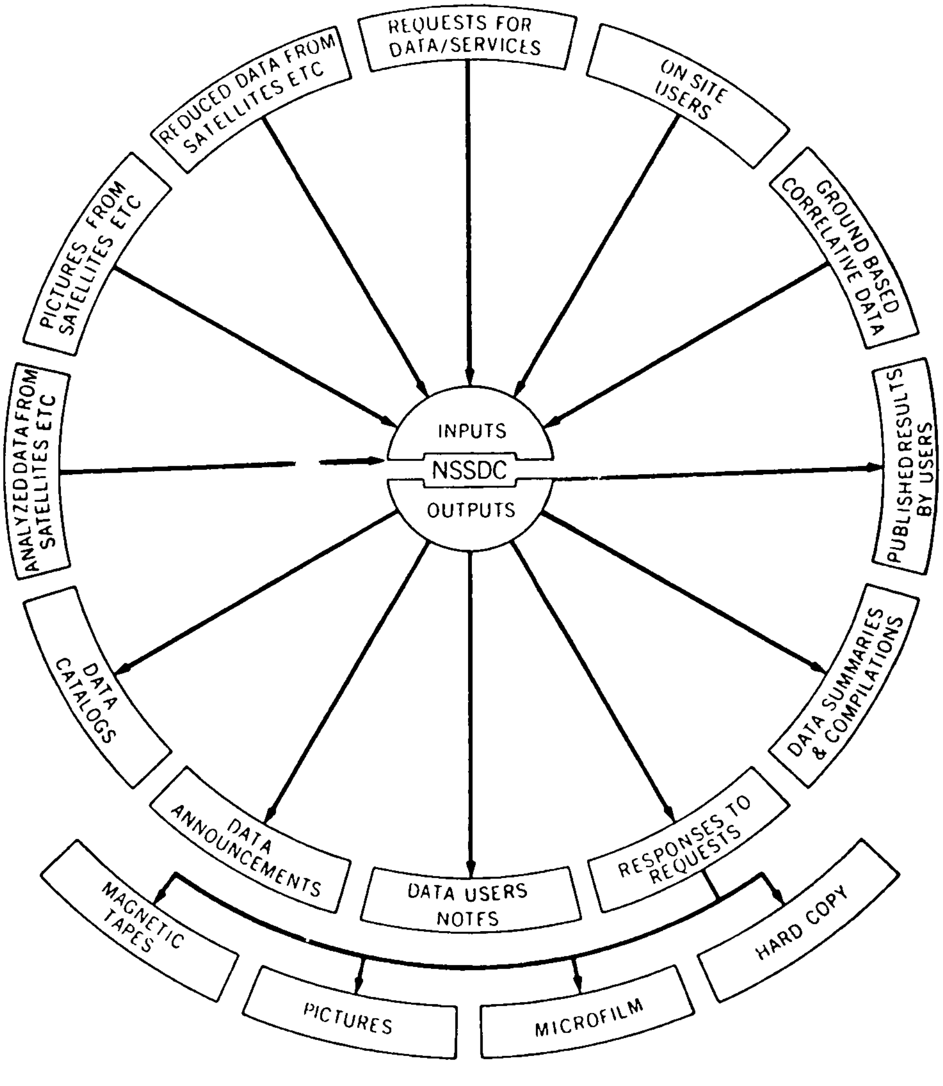


Figure 8. 5-6. A Summary of the Activities and Products of the National Space Science Data Center

DISCIPLINES	SUCCESSFULLY FLOWN EXPERIMENTS	SOME DATA AT NSSDC
IONOSPHERES & RADIO PHYSICS	86	12
PLANETARY ATMOSPHERES	96	20
PARTICLES & FIELDS	396	54
SOLAR PHYSICS	28	11
ASTRONOMY	35	3
PLANETOLOGY (INC SELENOLOGY)	127	45
TOTAL	768	145

AS OF MAY 17 1968
AS OF SEPTEMBER 17 1968

Figure 8.5-7. Data on Hand versus Successful Experiments

Function	Types of People	No of People
Management	R&D Administration	3
Systems	Planning & Development	2
	Analyst	4
	Operations	2
	Maintenance	1
	Technician	1
Data Acquisition	Space Scientist	9
Programming	Programmer	8
	Keypunch	1
Computer Services	Data Technician	7
Publications	Technical Information	1
	Writer/Editor	4
	Technician	1
	MTST* Operator	1
Storage & Reproduction	Technician (requests)	2
	Technician (data)	5
	Technician (photo)	5
	Technician (microfilm)	1
Research & Analysis	Space Scientist	3
	Technician	1
Administration	Administrator	2
	Clerical	5
	TOTAL	69
*Magnetic Tape Selectric Typewriter		

Figure 8.5-8 Type and Number of Personnel

the on-line retrieval aspects of NASIS provide for operating from a variety of terminals (or in batch mode). NASIS retrieval enables the user to expand and display (review) the terms of index (cross reference) files, select desired index terms, combine sets of documents corresponding to selected terms and display the resulting records NASIS will allow the user to print (record) this information on a high-speed printer if desired

NASIS also provides the ability to store (save) the strategy (NASIS commands) of any given session the user has executed NASIS has a searching and publication ability through generalized linear search and report generating modules which may be performed interactively or in a batch mode The user may specify formats for the terminal from which he is operating

The system features an interactive user's guide which explains the various commands available and how to use them, as well as explanations for all system messages This "explain" capability may be extended, without program changes, to include descriptions of the various files in use

Coupled with the ability of NASIS to run in an MTT (Multi-terminal task) mode is its automatic accumulation of statistics on each user of the system as well as each file

NASIS's ability to handle the storing of data was implemented to complement its retrieval abilities A wide variety of files are handled with variable length fields and records which can be defined, created, and maintained with no program modifications File definition can be done on an interactive basis This flexibility is possible because NASIS is based on a universal-record-format and a descriptor-driven file access

Although the file maintenance is typically handled in batch mode, a correct facility is provided to allow the interactive creation of maintenance transactions

The NASIS system was designed for a virtual-memory, time-shared, paged environment. It is written primarily in PL/I with input/output modules written in assembler The current implementation is running on an IBM 360/67 under the TSS operating system An overview of the system is shown in Figure 8 6-1

Because the system is primarily software, and since it is addressable through terminals which communicate through telephone lines, it is not committed to a particular geographic location Lewis is currently developing a prototype Earth Resources system on a one year program under Interagency agreement with the department of Interior Plans are not complete for the location of the eventual operational system

8.7 JET PROPULSION LABORATORIES (JPL) EXISTING CAPABILITY

The JPL facilities include

- Data Processing Center
- Mission Control Center for deep space probes
- Archiving Center

The Data Processing Center performs the same preprocessing functions as described in subsection 8 5 1, Preprocessing for Users, except on a smaller scale There are within JPL, a total of 49 computers which support all of the laboratory's computing needs including preprocessing

This includes the control of, and data handling from, the Deep Space Net communications system

The Mission Control Center is a dedicated facility used for deep space probes and is served by a pair of IBM 360/75 computers

The Image Processing and Archiving capabilities are discussed in the following sections.

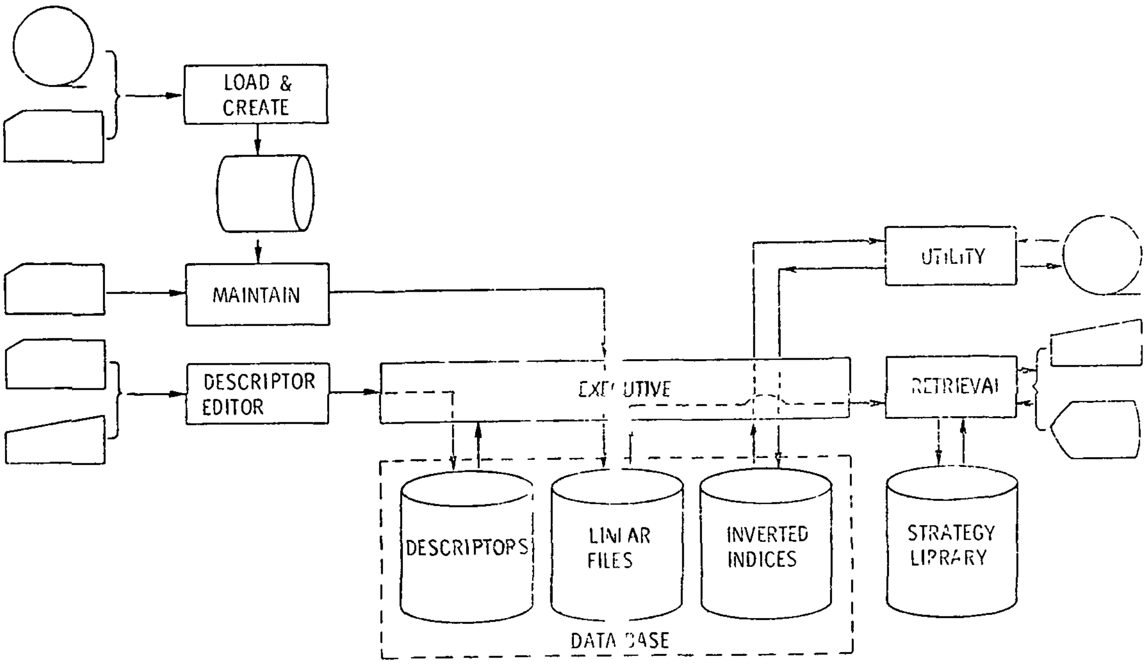


Figure 8 6-1 System Overview

8.7.1 IMAGE PROCESSING

Mars 71 generates 60 images per day These images are received via telemetry and enter the process flow shown in Figure 8.7-1, MARS 71 Data Flow Shaping and filtering are done in real time The day's 60 images are rectified and scaled and converted to film, then sent to the principal investigator for his selection He selects twenty-six, limited by the ability of the IBM 360/75 to do the processing that he requests within eight hours The results are digitized and returned to the investigator

Cost to process each photo can be calculated at about $1,000 based on the flow chart above Projections of future costs suggest a reduction to $100 per image through the development of new algorithms and technology A further reduction approaching $10 per image may be possible when processing the number of images expected in the Space Station experiment program (Application of the Production Functional Curves)

In addition to the imagery above, ultraviolet data is received, processed and formatted. Detailed analysis routines include filtering, enhancement, and stretching All processing is done off-line.

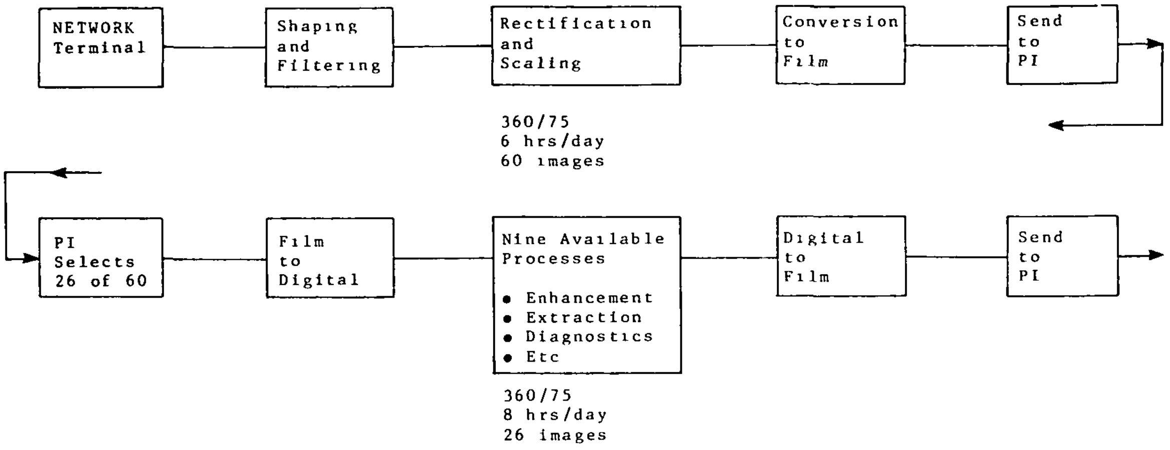


Figure 8 7-1. MARS 71 Data Flow

8.7.2 ARCHIVING

JPL has generated an archiving system in support of its deep space probes Turn-around time of the system is 24 hours Retrieval can be done on the basis of

- Mission time
- Latitude
- Longitude
- Lapsed time
- Information content

A catalog is published on a daily basis, containing abstracts of the data stored The abstracts are generated normally with close interaction with the principal investigator The catalog is disseminated in hardcopy, and is maintained on magnetic tape for automatic imaging from a remote terminal

Raw data is kept on magnetic film and on 75 MM roll film in the case of imagery Although no image data has been purged, to date, the total image file is contained in three computer card storage units Processed and correlated data, other than the master mission tape, is kept in an immediate access file for one year and then goes into a subactive file where it is kept for three years After three years the data is transferred to NSSDC at GSFC. The master mission tape is stored indefinitely since the mission is not repeatable However, JPL has only accumulated approximately 5,000 tapes in the last three years This will increase with Mariner 71, but not significantly

Sample retrieval products are shown in Figure 8 7-2 and Figure 8 7-3.

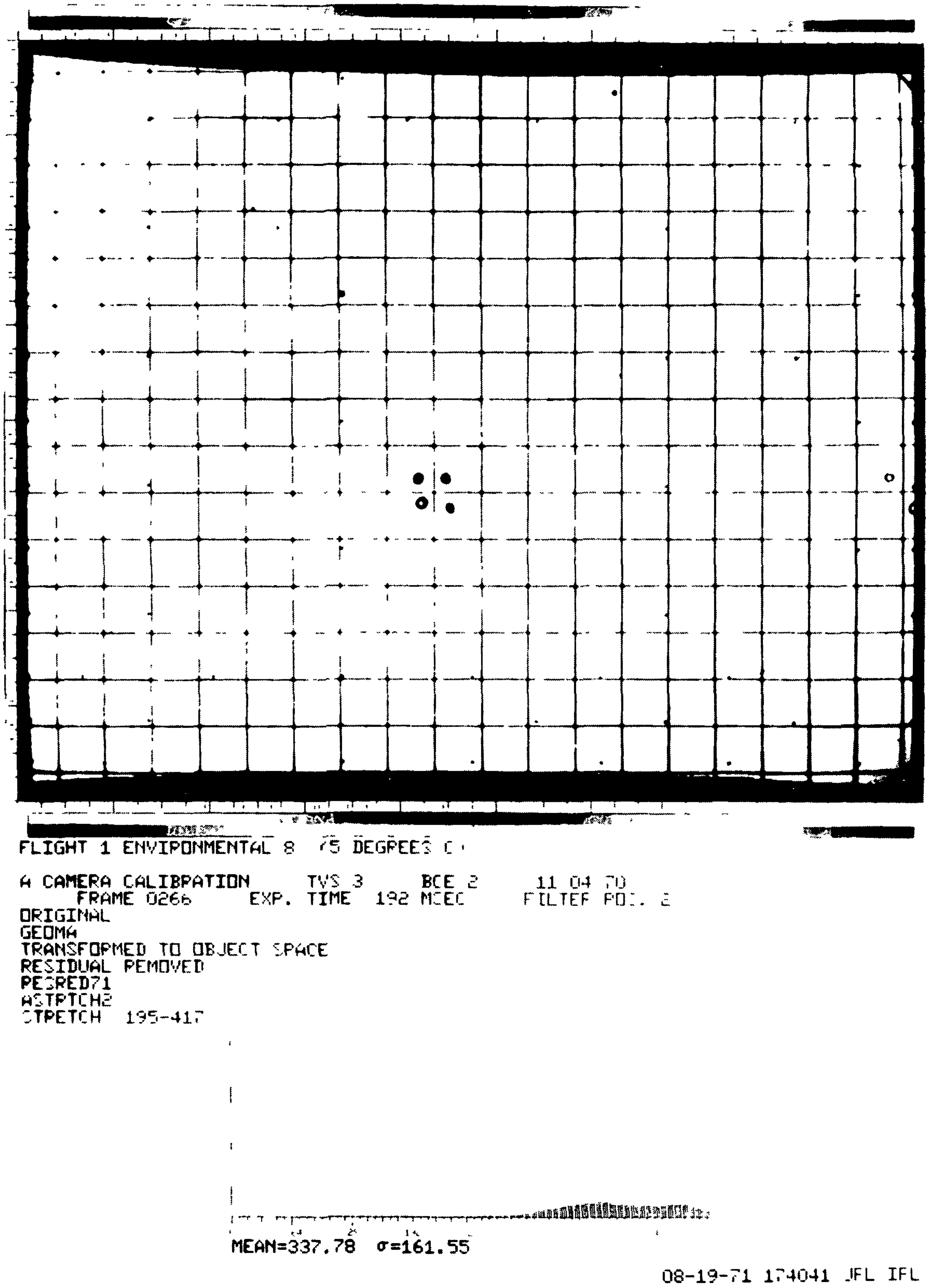
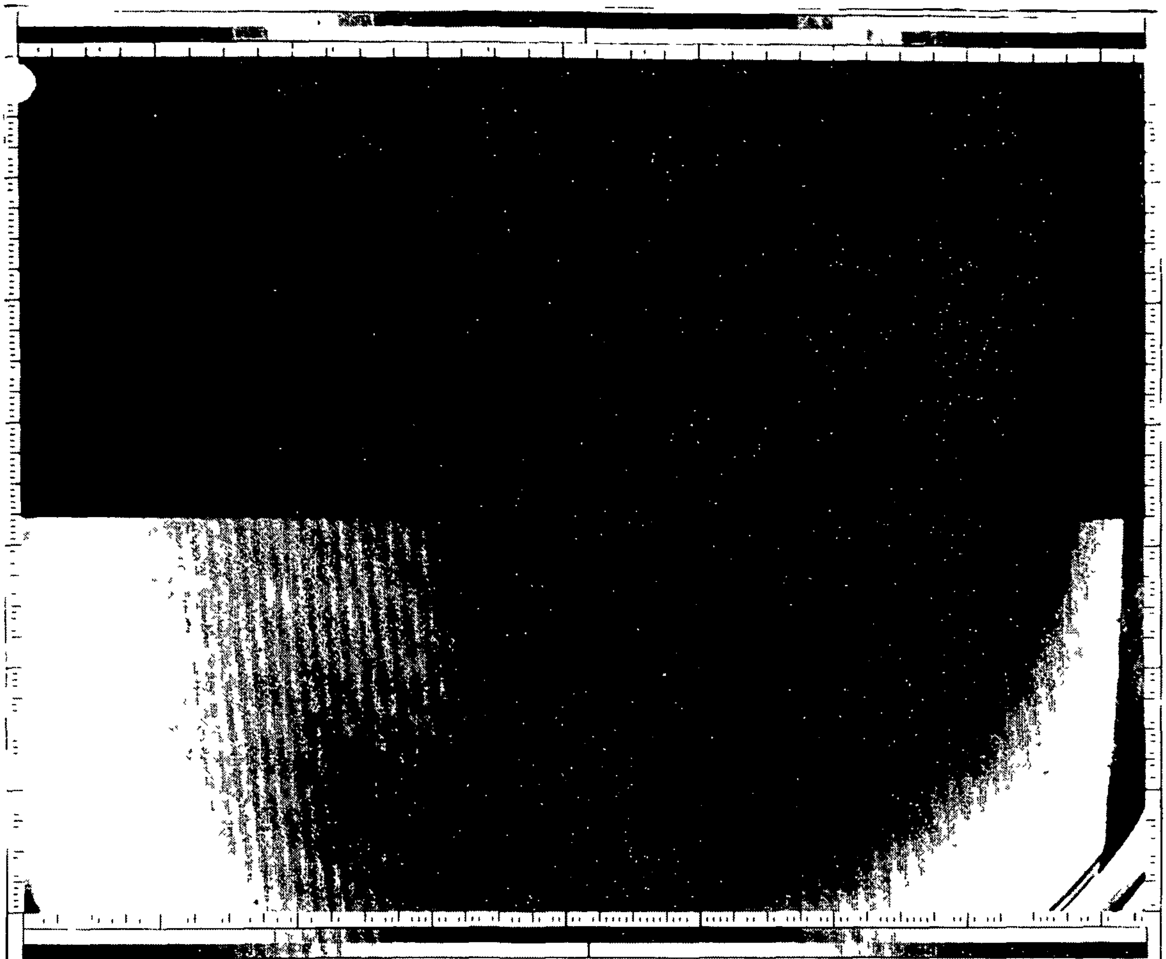
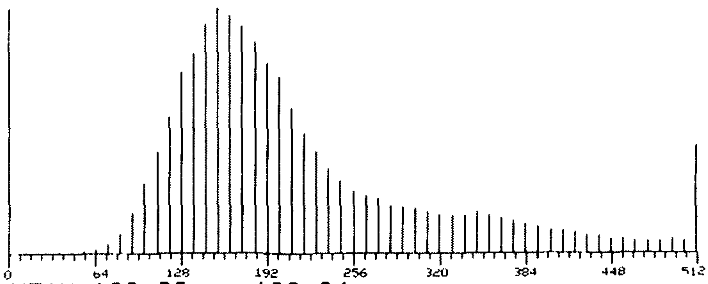


Figure 8.7-2. JPL Sample Retrieval Product - I



MARINER 9 ***B******* YR 71 DAY 275 GMT 062701 DAS TIME 00603702
PICTURE NUMBER * O*** EXP TIME 6144 MSEC FILTER POS *
ALT ***** KM APPROX WIDTH **** KM APPROX HT **** KM
VIEW ZENITH ANGLE **** SOLAR ZENITH ANGLE **** PHASE ANGLE ****
LONGITUDE-CENTER ***** CORNERS ***** ***** ***** *****
LATITUDE--CENTER ***** CORNERS ***** ***** ***** *****

STRETCH 20- 76



MEAN=100.83 σ=128.94

10-02-71 173139 JPL/IPL

Figure 8.7-3. JPL Sample Retrieval Product - II

8.8 EROS DATA CENTER - SIOUX FALLS, SOUTH DAKOTA

A Data Center in Sioux Falls, South Dakota, is operated by the EROS program of the Department of the Interior to provide access to ERTS imagery for the general public, industry, educational institutions, and foreign and domestic government agencies at all levels The Center serves all persons and groups not qualified as ERTS Principal Investigators to receive the imagery directly from NASA

In addition to the reproducible ERTS imagery, the Center also holds NASA aircraft imagery, current USGS aerial photography, and computer compatible tapes of ERTS and NASA aircraft data Facilities are available for imagery storage, retrieval, reproduction, and dissemination, and for user assistance and training

8.8.1 ERTS IMAGERY

ERTS imagery, originally processed at the Goddard Space Flight Center, NASA Data Processing Facility (NDPF), is a significant part of the Data Center imagery file Each scene, covering 34,000 square kilometers (10,000 square nautical miles) is imaged seven times from ERTS-A and eight times from ERTS-B three images from the Return Beam Vidicon (RBV) and four or five images from the Multispectral Scanner The raw data is either bulk-processed and provided to the Data Center in the form of 70mm film, or precision-processed and provided on film at a scale of 1 1,000,000 The Data Center has a catalog of the ERTS imagery and a browse file including only one RBV image and one Multispectral Scanner image per scene for evaluation of coverage and cloud cover The image formats are the same as those available from the NDPF.

Copies of bulk-processed individual images and color composites, derived by processing the three RBV and four MSS images together, are available as

contact paper prints contact film positives contact film negatives	roughly 6 35 x 6 35 cm

or

1 1,000,000 (3 38X enlargement) paper prints 1 1,000,000 film positives 1 1,000,000 film negatives	roughly 22 86 x 22 86 cm including marginal data

Copies of precision-processed images may be obtained only at scales of 1 1,000,000 or larger These images have been rectified to truly orthographic photographs and have been overprinted with the UTM grid Both individual images and color composites at 1 1,000,000 are available in various forms

paper prints film positives film negatives	roughly 22 86 x 22 86 cm including marginal data

Only about 5 percent of the images available in the Data Center are precision-processed

Orders for all the above items will ordinarily be filled within a week of receipt of the request.

Paper prints of individual bulk or precision-processed images enlarged to a scale of 1 250,000, or a paper print color composite at the same scale may be ordered However, it will take at least two weeks to fill such a request

Orders for other forms of the ERTS imagery will be honored whenever possible, but delivery time and costs will be determined on an individual basis Film negative and film positives of 1 250,000-scale enlargements of ERTS imagery are in this category

8.8.2 NASA AIRCRAFT IMAGERY

Imagery obtained by NASA, as part of its Aircraft Program in support of the development of Earth Resources Surveys by aircraft and spacecraft, is processed at the Manned Spacecraft Center This imagery was acquired for specific purposes and to varied specifications as to time, areal coverages, and sensors, and is primarily of test sites within the continential United States A catalog of this imagery, and a browse file, are also at the Data Center

Copies of these images are available at contact scales and enlargements, in color or black-and-white, on film or on paper Each image is reproduced with marginal information that provides, among other things frame number, date, geographic coordinates, and order number in an understandable code A request for reproductions is normally processed within one week

8.8.3 USGS AERIAL PHOTOGRAPHY

Aerial photographs, made by the U S. Geological Survey (USGS) primarily for purposes of topographic and geologic mapping, are available from the Data Center The vast majority are black-and-white, vertical photographs at a scale of approximately 1 24,000, and contact prints are 22 86 x 22 86 cm (9 x 9 inches) format Catalogs of the USGS photographs and a browse file for evaluation of coverage are available at the Data Center

All photographs are available at contact scales and enlargements, on film or on paper Each scene is reproduced with marginal information that provides among other things frame number, date, geographic coordinates, and order number in an understandable code Photographs obtained prior to 1941 are held by the National Archives and Records Service Material is available on request but not within the normal one week reproduction time.

8.8.4 MAGNETIC TAPES

Computer-compatible magnetic tapes of both ERTS data and NASA Aircraft Program data are available for reproduction through the Data Center Of the total ERTS data, about one percent of the raw RBV data, about five percent of the raw Multispectral Scanner data, and one hundred percent of the precision-processed data are available in this form Tapes of data from Aircraft

Program investigations, as with NASA Aircraft imagery, cover a variety of sites and situations, but all that have been produced are available

8.8.5 BROWSE FILES

The catalogs of ERTS imagery, Aircraft Program imagery, and USGS produced on 16mm film are available for purchase The browse files have two indexes to identify scenes at high speeds Kodamatic Indexer Code Lines and Image Control Each film is also designed so that it can be cut and mounted by the user for microfiche presentation Browse files for the ERTS data are updated every 18 days and are available on a subscription basis Updating of the other browse files is irregular and films must be purchased individually

8.8.6 THEMATIC OR SPECIAL SUBJECT MAPS

Thematic maps produced systematically or mechanically from ERTS imagery are available at the Data Center The special subjects covered are extent of standing water, infrared-reflective vegetation, massed works of man, and snow cover Maps are prepared for the entire United States or parts thereof if the subject, as for example snow cover, is not applicable to the entire country The maps are produced as single-color transparent overlays to a base map series, both with UTM grid to expedite registration

The subject data are extracted periodically for comparative purposes in order to detect changes in these dynamic phenomena The data for the overlays are also available on magnetic tape

8.8 7 SERVICES

The Center also provides a variety of support services, as follows

- Search and Retrieval - request by mail, phone, or visit
- Assistance in Interpretive Techniques -
  - densitometers
  - additive color viewers
  - stereo viewers
- Training -
  - cartography
  - interpretation
  - scientific research

8.9 DEPARTMENT OF COMMERCE

The Department of Commerce operates two divisions of particular interest to this study the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Science Services Administration (ESSA)

In order to perform the tasks for which they are responsible, they have implemented data centers as follows

- National Oceanographic Data Center
  Rockville, Maryland

- National Climatic Center
  Ashville, North Carolina

- National Geophysical Data Center and
  Aeronomy and Space Data Center
  Boulder, Colorado

- Environmental Science Information Center
  Rockville, Maryland

These Centers are primarily archives with computational capability to allow users to request data in the format desired The computational capability represents a potential to handle a part of the special processing required to handle the data load defined in this study Basic procedures and hardware are available Implementation of special software would be the prime requirement

SYSTEM DEFINITION 9

9.1 INTRODUCTION

This section describes the derivation of the data flow system which meets the objectives of the study, which called for a low-cost, interactive system Lowest possible cost is attained by maximum use of present NASA facilities and mutually beneficial cooperation among NASA and other government agencies Interaction between user/agent and experiment was planned into the system as a means of controlling the flow of useable data

The principal guidelines in this phase of the study were as follows

- minimize early expenditures
- low cost
- maximize use of existing facilities
- minimize archiving by NASA
- follow natural lines of responsibility
- minimize special processing by NASA
- maintain information management responsibility in NASA

9.1.1 SCOPE

Data flow was considered from "Source-to-User," from the instrumentation aboard the orbiting spacecraft with primary emphasis on the handling of data by NASA The time frame considered embraced the Initial Space Station (ISS) period through te period of the Growth Space Station (GSS)

9.1.2 METHOD

Two basic user models were initially developed from the requirements analysis described in Section 2 of this report These two models are as shown in the following figures The Applications User Model, Figure 9 1-1, represents principally the users of earth resources data, who are shown working through a government agency to use data supplied by NASA systems Especially in later periods (GSS) other applications users are expected to interface with the systems directly through the pictured NASA User Service For example, experiments conducted within the MS/MS discipline during the ISS period are expected to yield practical applications in the GSS period

The Science User Mode, Figure 9 1-2, typifies operations within the scientific disciplines, e g , Astronomy, Physics, Life Sciences Very often a group of interested users will organize under the cognizance of a University, where they will have the facilities at their disposal to process raw data In other cases a scientific organization such as Kitt Peak can with

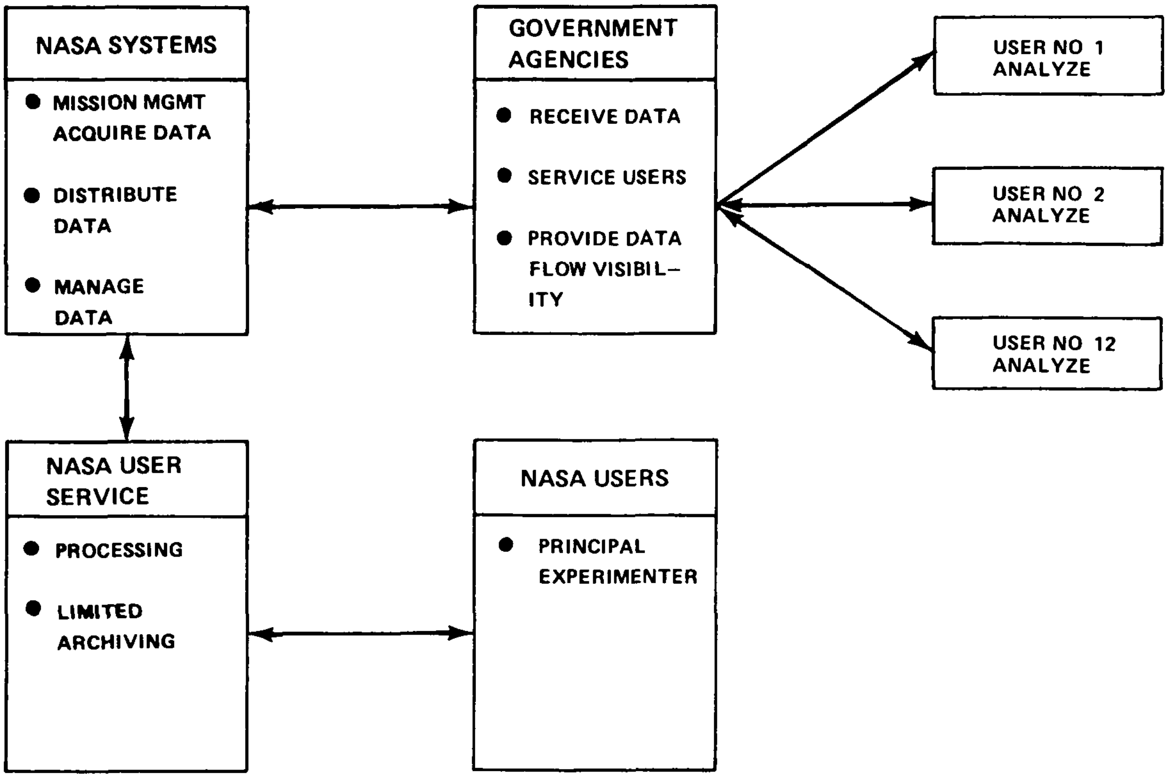


Figure 9. 1-1. Applications User Model

interface directly with NASA and accept raw data, performing all processing within its own facilities and serving many users as shown Lastly, there are the NASA scientists and guest scientists who, working with the NASA User Services will conduct their own experiments, principally on NASA premises

From these basic models, using the concepts developed in the concept formulation phase of the study (dissemination, interaction, archiving, etc) a system baseline concept was developed for approval by NASA With approval, the concept was further developed into a system definition, detailed enough to permit development of a plan for implementation The succeeding sections describe the system and the logic of its derivation

9.2 BASELINE SYSTEM DEVELOPMENT

Having translated the user requirements into the minimum set of user models just described, the next step was to derive a functional system design capable of handling all of the data forms specified in the requirements analysis, and meeting all the user requirements in terms of interface definition, interaction requirements, processing, archiving, and timeliness of data delivery The system was considered from sensor to user in order to include onboard system requirements, orbit-to-ground communications and all data handling and

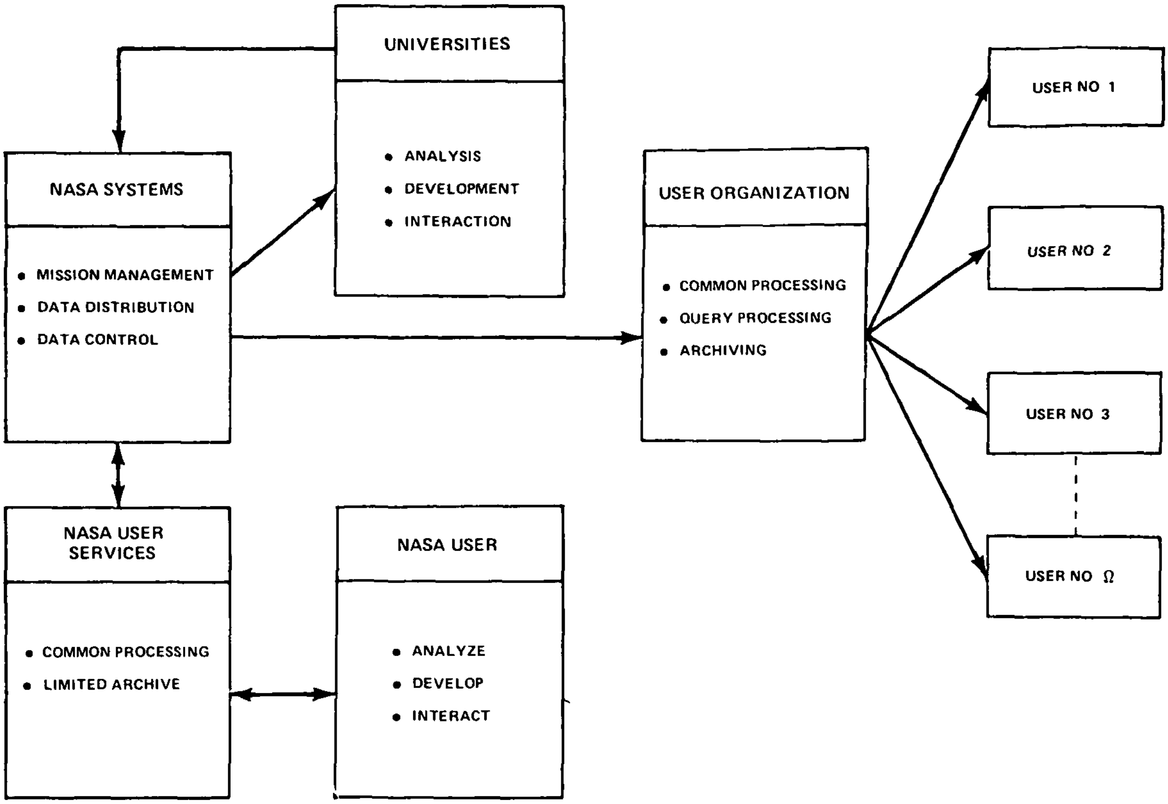


Figure 9. 1-2. Science User Model

shipping requirements on the ground The resulting baseline system and an initial quantitative test of its feasibility are described in this section

9.2.1 FUNCTIONAL SYSTEM DEFINITION

The overall functional data flow system, Figure 9 2-1, encompasses all the data handling functions required to satisfy the requirements described above

Data is delivered both by RF link using the Tracking and Data Relay Satellite (TDRS) and by shuttle physical return The data forms essential to the system development are film, digital, and analog Details of the major functions shown in this figure are described in the following sections

9.2.1.1 Data Flow System Onboard

The onboard system, Figure 9 2-2, serves the purpose of collecting and formatting data to the extent that subsequent data systems functions can be formed efficiently and cost effectively

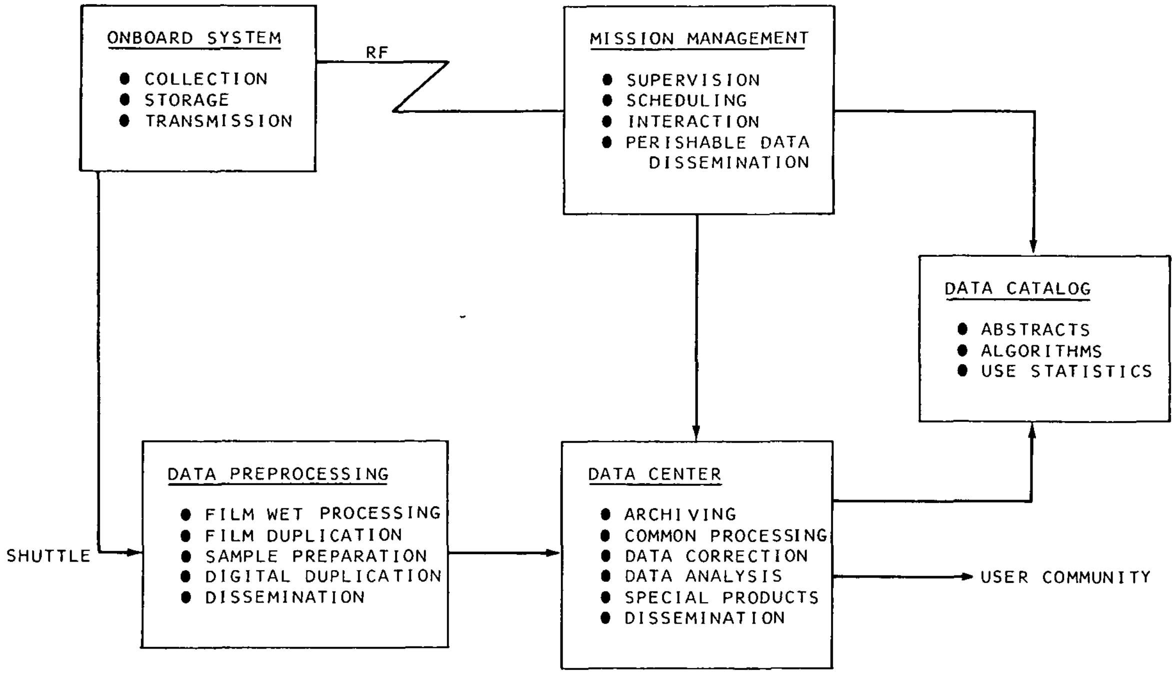


Figure 9. 2-1 Overall Functional Data Flow System

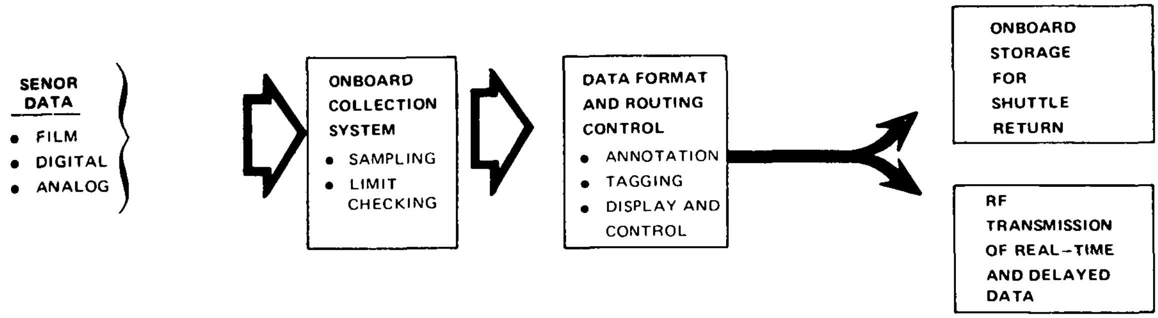


Figure 9. 2-2 Data Flow System Onboard

Sensor data from a large variety of instruments is recorded on film or tape and retained on-board for delivery by shuttle In addition, selected data is transmitted to ground immediately or at a prescheduled period within a few days This data falls into one of the following classes

- Perishable data
- Data required for Mission Management
- Data required for user interaction

9.2.1.2 Data Return

Data is returned by transmission through the Tracking and Data Relay Satellite (TDRS) system and by the Space Shuttle which delivers 26 days of recorded and collected data each 30 days

The TDRS system which was specified as baseline to the study has adequate bandwidth capability to handle the maximum data rates in both the ISS and GSS time periods However, transmission of data through the TDRS to the ground network is periodically interrupted by two different mechanisms In the two satellite, single ground station TDRS which was specified as baseline to this study, there is a ten minute period during each orbit of the Space Station when it is out of line-of-sight of both communications satellites Data generated during this period for real time transmission must be buffered until communications are reestablished This requires the following buffering accommodations on the spacecraft

For ISS	Digital	4 1 X 10^9 bits
	Video	10 MHz Five Minutes

These requirements then are recommendations for modification of the baseline Space Station Information Management System

In addition, about once each 88 days, because of solar eclipse, solar power in the communication satellite is interrupted for about 40-72 minutes During this time the satellite switches to low power and bandwidth is reduced This however, is a minor problem and need only be taken into consideration when scheduling transmission

9.2.1.3 Data Preprocessing

Data preprocessing functions are shown in Figure 9 2-3 Data returned from space undergoes initial processing designed to fulfill one of two timeliness objectives one, the real time data requirement satisfied by the real time data processor which is used to select, format, buffer and convert data to a form required to display and interpret onboard conditions, two, activity such as scheduling system maintenance, and operational assistance also depending upon the availability of timely data The remainder of the preprocessing system provides means to receive and buffer data according to discipline Preprocessing subsystem output shown as typical of a system that operates on data received via telemetry, generates an output usable in the next data handling element In this case data is transmitted electronically over a broadband network to the designated data center A preprocessing subsystem option of sorting and recording all nonreal time data onboard would replace the buffer and broadband systems with a shipping center to distribute onboard recorded magnetic tape

9.2.1.4 Data Center

Data from the preprocessing center is received at each of the distributed data centers (Figure 9 2-4) either over a broadband network or in reels of magnetic tape where further processing is performed Film and samples in all cases are received at the appropriate

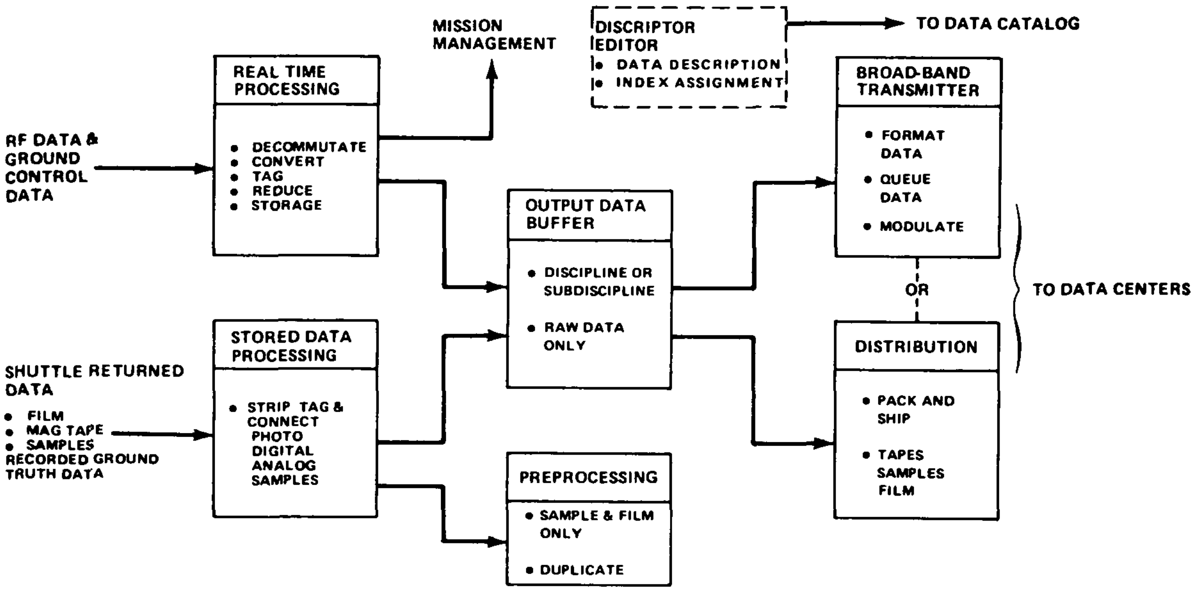


Figure 9. 2-3. Data Preprocessing

data center The processing in each case is determined by the data type and user group As an example, image data is received as indicated and is common processed to provide data enhancement needed by a number of users Both raw data and products of the processing are placed in an archive (Data Library) where they are made available to a community of users served by that data center Other centers may also access the library to obtain either data or processing algorithms used in the center Provisions are made within each center to provide special output products to the user community These may consist of unique data forms or special enhancements

Each center provides its own management and planning organizations as shown across the top of the figure The function shown across the bottom are maintenance functions necessary to keep the system updated and manageable

9.2.1.5 Data Catalog

The Data Catalog shown on Figure 9 2-5 has the responsibility of listing indices, abstracts, and location of all data, data products, and processing algorithms used The data listed will consist of both space and ground data as well as ancillary data (calibration curves and mission data) necessary for interpretation The catalog may be accessed directly as will online remote terminals or indirectly by mail or phone query It contains an interactive capability to permit the user to conduct a guided search for data of interest The catalog may be co-located with one of the archives to simplify implementation or it may be located separate and independent of all other system facilities

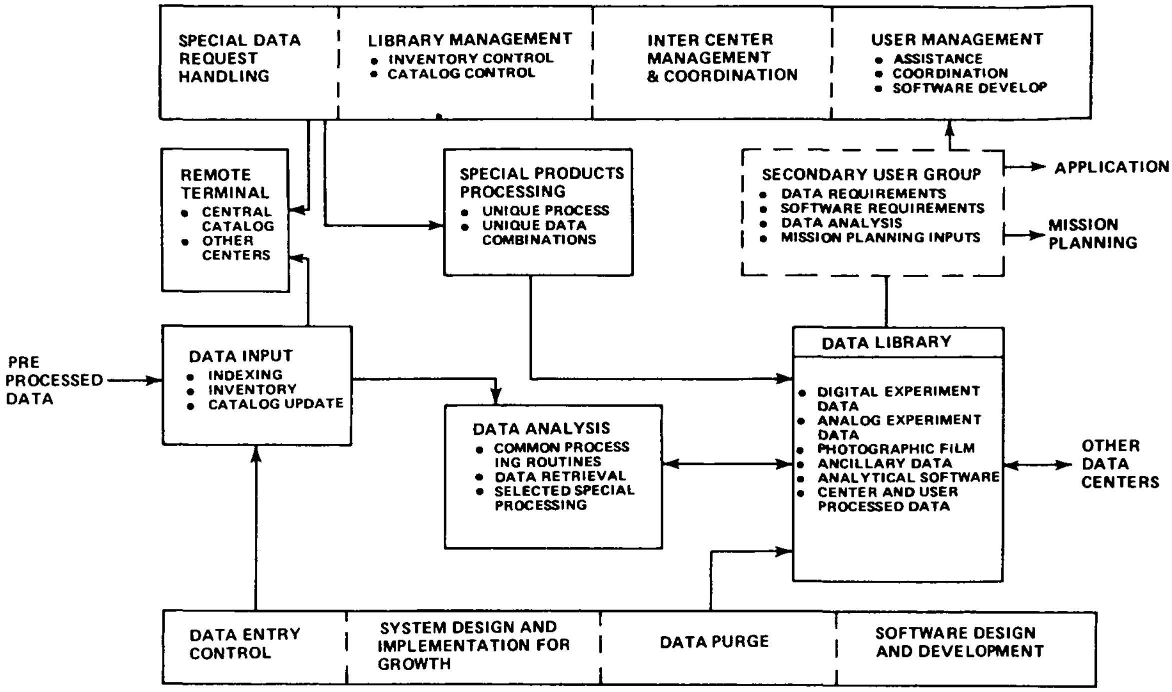


Figure 9. 2-4 Data Center

9 2 1.6 Mission Management

The real time interface between the ground operations and the operations onboard the space vehicle is provided by the subsystem shown in Figure 9 2-6 All or a portion of the telemetered data is processed in real time for the purpose of providing supervisory visibility over a mission and experiment operations The elements of the mission management system provide all the operations Included in the real time ground system is a temporary bulk storage large enough to accommodate all data received including highly perishable data that must be made immediately available to the proper experimenters located either remotely or within the mission management facility

The role of mission management has been changed from the traditional role of controller to that of a mission support activity As such it retains only the responsibility to monitor operations, do mission scheduling, and supervise experiment interactivity

9.2.2 NASA CAPABILITY ASSESSMENT

A measure of the capability of existing NASA facilities to handle the data preprocessing load for which the baseline system concept was derived is a test of the feabisility of implementation Consequently, a hypothetical assignment of roles was made, based on a comparison of digital requirements with facility experience and capability in terms of preprocessing throughput

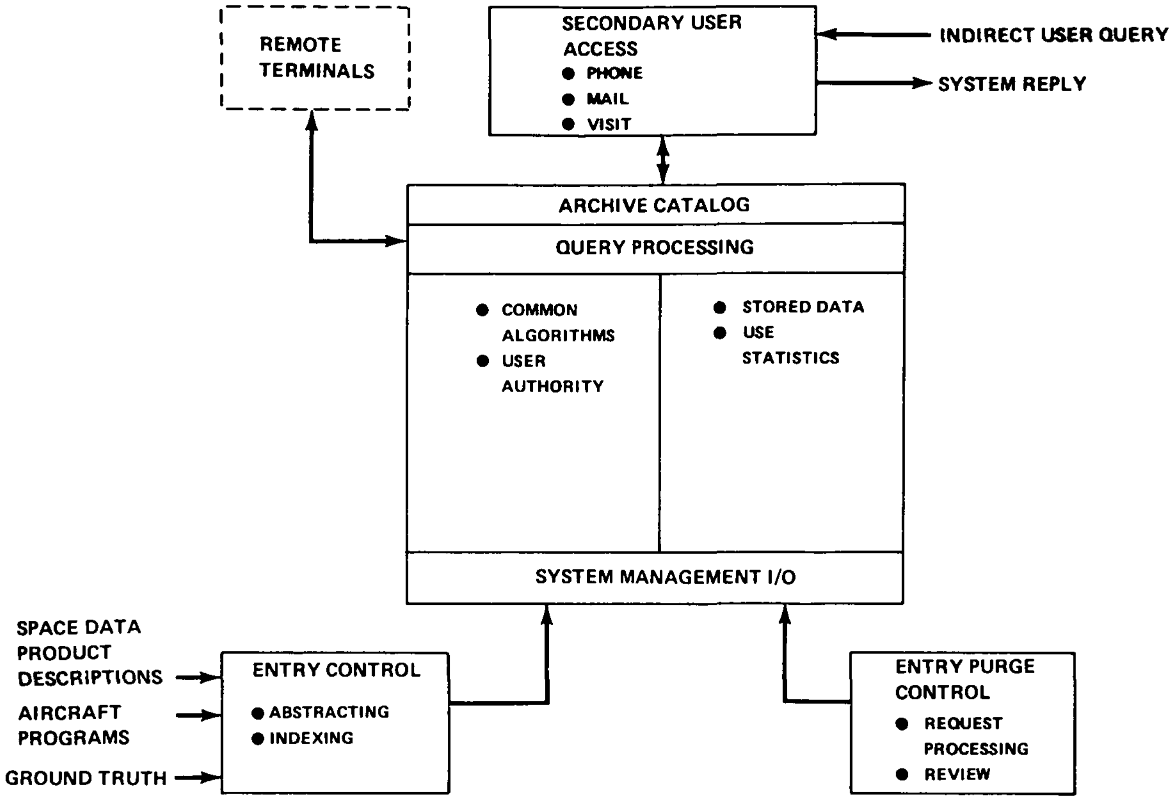


Figure 9 2-5 Data Catalog

9.2.2.1 Hypothetical Assignments

The rationale for role assignments is as follows, in the logical order of the decision process

1	KSC	Launch Operations – Recovery Initial Handling	• Dedication to launch • Assume recovery handling
2	JPL	Deep Space	• Deep Space commitments
3	GSFC	Physics	• Experience • Software available • Throughput inadequate but requirements within expected growth
4	MSC	Life Sciences	• Experience • Software • Facilities

5	MSFC/Slidell	MS/MS	• Experience • Laboratories • Support Arrangements
6	MSFC/Slidell	Astronomy	• ATM Experience • Processing Capability
7	MSFC/Slidell	Technology	• Processing Capability
8	MSFC/Slidell	Comm/Nav	• Processing Capability
9	MSC	Mission Management	• Experience • Facilities
10	Non-NASA (To be Assigned)	Earth Resources	• NASA facilities inadequate • Other User Agencies implementing facilities

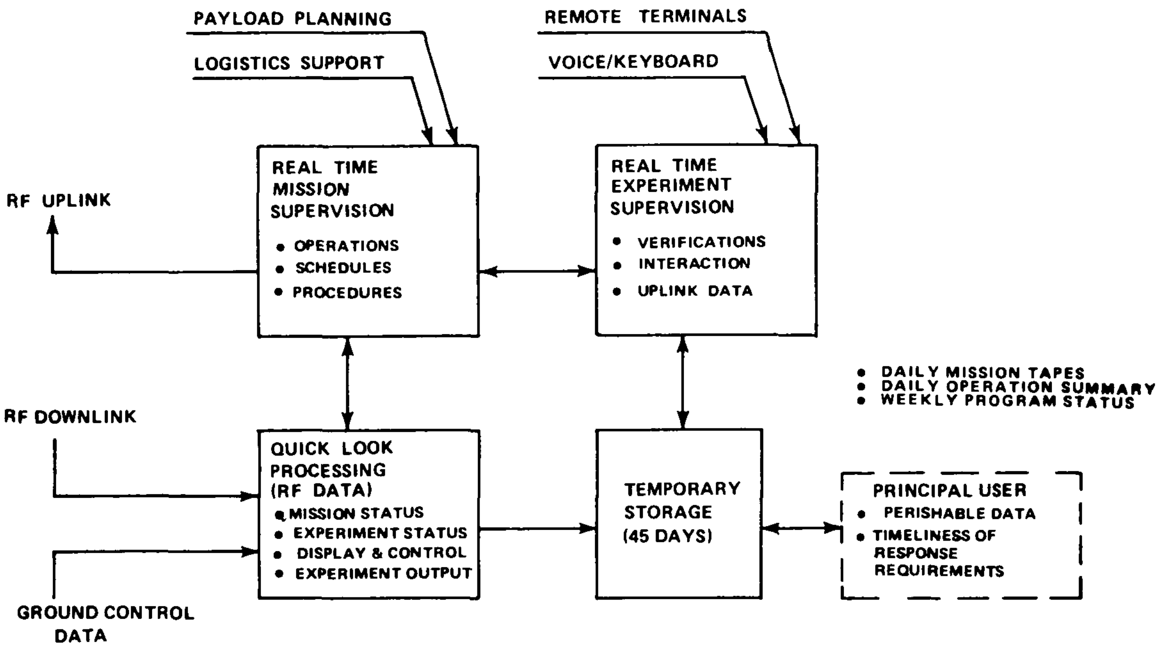


Figure 9. 2-6. Mission Management

In Steps 6 and beyond, with assignments previously made, other centers had inadequate residual processing capability to assume the additional responsibility

With these assignments made, the measure of feasibility is shown in Figure 9.2-7.

FACILITY	DISCIPLINE	REQUIREMENTS	CAPABILITY
GSFC	PHYSICS	10 0 X 10^{10} BITS/MONTH 1 4 X 10^{6} FRAMES/16 MM/MONTH 0 33 MHz VOICE/192 HRS 835 IMAGES/MONTH	12 X 10^{10} BITS/MONTH OK OK 39,918 IMAGES/MONTH
MSC	MISSION MANAGEMENT	0 5 X 10^{6} BITS/SEC 305 6 HR/3 3 MHz VIDEO/MONTH EXPERIMENTER INTERACTION 45-DAY BUFFER	NEW INTERFACE HARDWARE NEW DISPLAY AND COMMUNICATION INTERFACE INTERACTION 7 3 X 10^{11} BIT BUFFER
	LIFE SCIENCES	1 8 X 10^{9} BITS/MONTH 52 HRS/4 MHz VIDEO/MONTH 6 X 10^{5} FRAMES/35 MM 1,000 FRAMES/70 MM SAMPLES	30 X 10^{9} BITS/MONTH OK OK OK OK
JPL	DEEP SPACE PROBES		
KSC	PRELAUNCH CHECKOUT SHUTTLE AND PAYLOAD		
MSFC/SLIDELL	ASTRONOMY	11 2 X 10^{8} BITS/MONTH 2,496 IMAGES/MONTH	
	MS/MS	13 X 10^{9} BITS/MONTH 225 HR/3 3 MHz VIDEO/MONTH SAMPLES	
	TECHNOLOGY	42 3 X 10^{9} BITS/MONTH 3 5 X 10^{5} FRAMES/16 MM/MONTH 111 HR/3 3 MHz VIDEO/MONTH 520 IMAGES/MONTH	
	COMM/NAV	67 6 X 10^{9} BITS/MONTH	
	TOTAL	12 4 X 10^{10} BITS/MONTH 3,016 IMAGES/MONTH 336 HR/3 3 MHz VIDEO/MONTH	57 X 10^{10} BITS/MONTH 4,320 IMAGES/MONTH OK
GOVERNMENT AGENCIES • DEPT OF COMMERCE • DEPT OF INTERIOR • DEPT OF AGRICULTURE • DEPT OF NAVY • CORPS OF ENGINEERS	EARTH RESOURCES	2 5 X 10^{11} BITS/MONTH 1 2 X 10^{5} DIGITAL IMAGES/MO 36,000 FRAMES FILM	

Figure 9. 2-7. Requirements versus Capability

9.2.2.2 Capability Summary

Capability of the NASA facilities to handle the expected data loads requires consideration of image handling capability as well as the digital processing considered in the previous section Figure 9 2-8 summarizes both the digital and image handling adequacies based on the assigned roles In all cases it can be seen that the driving requirement was the digital data, and facilities are universally capable of handling the required quantities of images

This figure also shows the gross residual NASA capability compared with the remaining requirements to handle Earth Resources data to be as follows

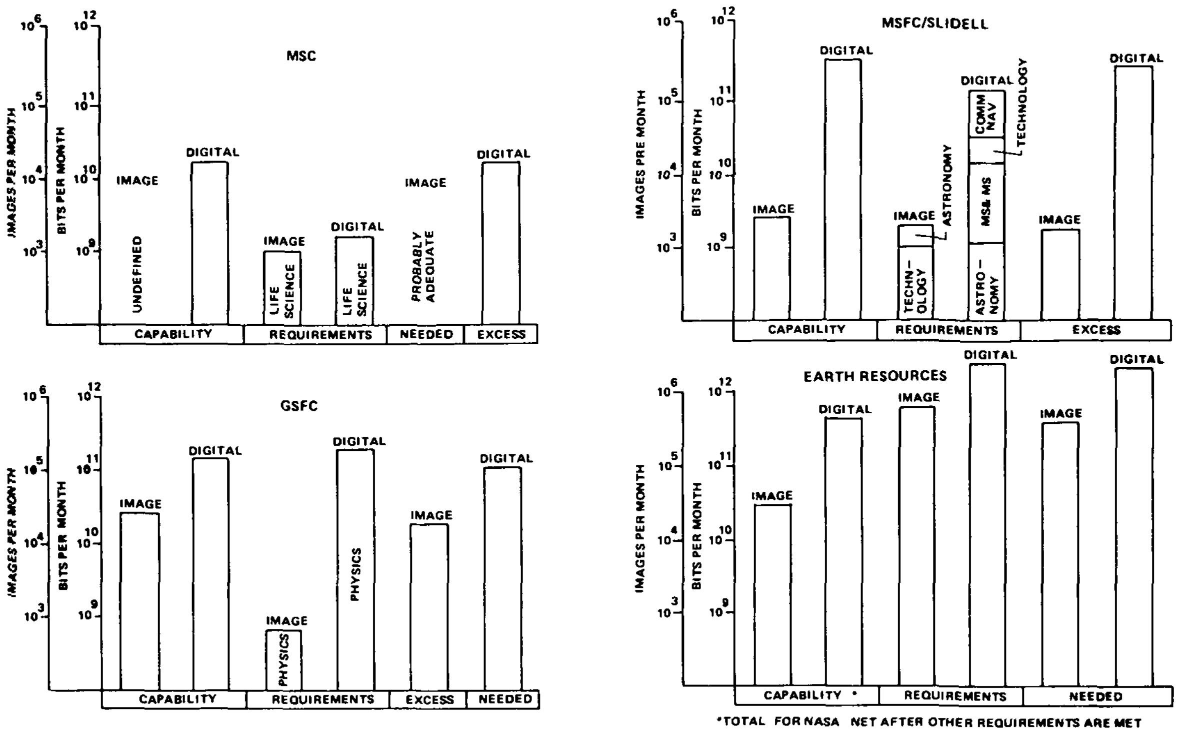


Figure 9. 2-8 NASA Data Handling Capability

Digital requirement	–	1 5 X 10^{12} bits/month
NASA residual	–	0 48 X 10^{12}
NET	–	1 X 10^{12} bits/month
Image requirement	–	36,000 frames/month
NASA residual	–	40,000
NET	–	excess capability available

9.2.3 BASELINE RESPONSIBILITIES

From the preceding functional system design and the analysis of NASA capabilities, a set of functional responsibilities can be defined These become a part of the baseline concept from which the proposed data flow system is derived

- NASA should perform initial data handling functions
  - Receiving data
  - Organizing data
  - Duplicating and delivering data

- NASA should perform vehicle and mission management functions
  - Prelaunch, launch, and operations supervision
  - Experimenter interaction
- NASA should maintain control and trackability of data
  - Centralized catalog
  - Entry Management
- Government organizations and facilities should be used to provide needed capacity for data processing
  - Follow along lines of existing responsibility
  - More involvement of existing user groups
  - Discipline oriented distribution
- Archiving should be provided by each discipline oriented center

9.3 PROPOSED SYSTEM CONFIGURATION

The proposed configuration for the Space Station Data Flow System is shown in Figure 9 3-1

9.3.1 FUNCTIONAL RESPONSIBILITIES

Inherent in the successful operation of the complex data flow system proposed here, are the functional responsibilities of the agencies involved The key responsibilities identified and recommended in this study are explained in this section

9.3.1.1 NASA's Role in Scientific Data Handling

Respondibilities for handling data from the six scientific and engineering disciplines are presently met by NASA, and the proposed data flow system continues this responsibility This includes the preprocessing and archiving of data Archiving includes corrected data as sent to the principal experimenters, and processed data, or results as returned from the experimenter

Information Management is reserved to NASA, and in support of this, NASA remains in charge of Mission Management, Experiment Interaction, and Data Cataloging

Mission Management includes the planning functions associated with scheduling experiments, data quality control, and RF return data handling, as well as the providing and scheduling of consoles and other facilities for user interaction with this experiment

Data Cataloging responsibility includes the classification and abstracting of data Abstracting is done on NASA premises by NASA personnel unless otherwise prearranged by the experimenter insofar as original data is concerned In the case of user processed data, NASA must

require the user to supply abstracts and indexing information when he submits processed data, with final indexing to be done by the NASA staff

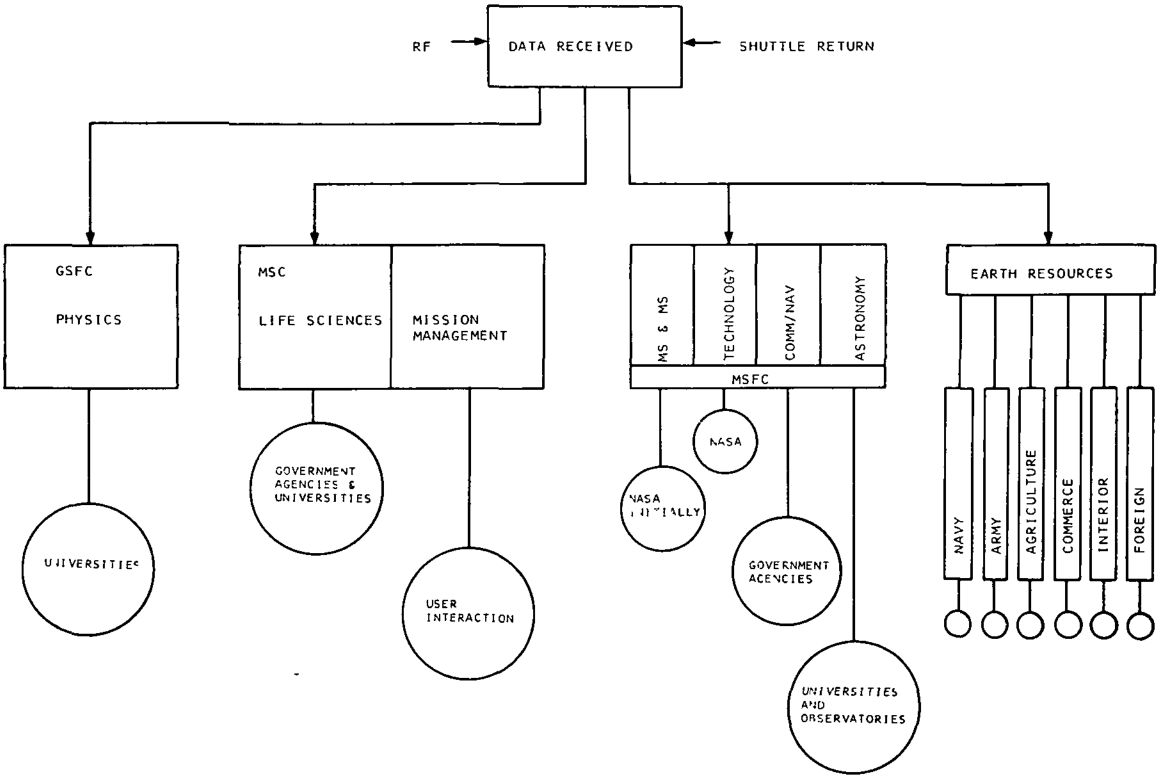


Figure 9. 3-1. Data Flow System

9.3.1.2 NASA's Role in Earth Resources

In the handling of Earth Resources data, NASA's role is more restricted than in the sciences. However, the restrictions are due solely to the assumption by other government agencies of the preprocessing, analytical processing, and archiving roles

Information Management is reserved to NASA, and in support of this, NASA remains in charge of Mission Management, Experiment Interaction, and Data Cataloging

Experiment Interaction, in the case of weather data is operated remotely by NOAA because of the perishable nature of the data and the uniqueness of the data requirements

9.3.1.3 Department of Agriculture's (USDA) Role

The Department of Agriculture is responsible for improvement programs requiring data on crops, forests, wild lands, soil conditions, water conditions, etc

To avoid unnecessary duplication of archives and processing facilities, the Department of Agriculture has already reached agreement with the Department of Interior for the joint

use of Sioux Falls and Regional facilities Archiving, preprocessing, and special emphasis will be done at the Sioux Falls, Earth Resources Observation System (EROS) for the regional centers who will service users

The Department of Agriculture is performing a great deal of research in developing techniques and utilization of high-rate multispectral data and other remote sensing data The details of their data centers, though they are available, have not been obtained for this study Each of the services within the department does have computation capability to support its functions, and with their research programs they are trying to upgrade these facilities for the handling of remote sensing data

9.3.1.4 Department of Commerce (DOC) Role

The Department of Commerce is responsible for promotion of safe and effective use of man's physical environment and the preservation of environmental quality Three agencies within the department have an interest in remote sensed data

The National Oceanic and Atmospheric Administration has interests in the following areas

- Meteorology
- Hydrology
- Oceanography
- Marine Resources
- Solid Earth (Geophysical)

The Maritime Administration is interested in data on harbors and related transportation and other systems that impact maritime operations

The Bureau of the Census is interested in population distribution

These interests imply a need for all Earth Resources data to be delivered to the designated Commerce Data Center

Presently Commerce maintains data centers as follows

- National Oceanographic Data Center, Maryland
- National Geophysical Data Cetner, Colorado
- National Climatic Data Center, North Carolina
- Agronomy and Space Data Center, Colorado

9.3.1.5 Department of Army's (Corps of Engineers) Role

The Corps of Engineers within the Army is responsible for the planning, design, construction, operation, and maintenance of works for improvement of rivers, harbors, and waterways for navigation, flood control, shore protection, preservation of navigable waters and emergency operations

The Corps of Engineers is engaged in research on the development of systems for the collection and processing of telemetered data from ground sensing stations, in reduction, analysis, and application of data acquired by the use of remote sensing instrumentation in fixed-wind aircraft The Corps collaborated in the analysis and evaluation of data obtained by sequential collation of ranges (SECOR) on Apollo 9 They are presently developing techniques for long-range planning

The specific capability within the Corps of Engineers as far as data centers are concerned has not been investigated, however, it is known that they do have the computation capability that could be adapted for handling remote sensed data Location of the Data Center shown in Figure 9 3-1 is not identified and it remains to be determined what particular subsets of experiment data must be reproduced for this center

9.3.1 6 Department of Interior's (USDI) Role

The Department of Interior is responsible for management of public lands of the United States, including the outer continental shelf, assessment and protection of the environment, gathering and dissemination of scientific knowledge on the resource environment of the United States and Antarctica and the presentation and enlargement of many public areas such as national parks and national monuments It is also concerned with the resources of the sea, primarily mineral and biological

Present plans call for implementation of a central processing and archiving facility at Sioux Falls, South Dakota, to handle data from the ERTS program in 1973 The system planned for joint usage with the Department of Agriculture will be expanded to include eight additional regional centers designed to help service users

The Data Center, Figure 9 3-2, at Sioux Falls was designed to

(1) Receive master tapes and/or images for NASA

(2) Duplicate and distribute copies of the raw data to clientele within the department and other agencies in resource/environmental organizations The initial demand for remote sensed data, specifically the ERTS return beam vidicon images, are approximately one million copies However, this may be a conservative estimate Sioux Falls was designed to do this

(3) Routinely and automatically extract the following statistical and map format resources information

a surface water distribution

b sediment distribution in water

c snow and ice

d. natural vegetation

e agricultural vegetation

f urban outlines

g changes in the above with time

(4) Relate the images to geographical coordinates subsystems

(5) Transform the photographic images into map form that scales of 1 250,000 and smaller

(6) Apply regional centers with data and specialized processing as required

9.3.1.7 Department of Navy

The Naval Oceanographic Office is concerned with such matters as ocean bottom topography, coastal erosion and storm damage, sea ice cover, sea traffic and oceanic currents, As such, it is a potential user of Space Station data on an operational basis as it is, experimentally, in ERTS

Subsets of Earth Resources data, particularly observations overseas are anticipated, representing an undefined portion of data

9.3.1.8 Foreign User Concepts

This study explored the collection and dissemination of non-United States' Earth Resources data only on a conceptual basis The result was a set of concepts that were judged worthy of further exploration

- Permanent receiving sites for overflights – In this concept countries would install fixed receiving sites for receiving direct observation data in real time, by transmission directly from the Space Station to the receiving site The using country would be responsible for all data handling An arrangement similar to this has been made with the Canadian government for receiving data from the ERTS satellite

- Mobile receiver sites for overflights – Section 3 3 4 of this report describes a similar mobile station that could be provided in lieu of the fixed station described above Such a facility might be provided on a rental basis

- Sort by country onboard – Data from obesrvation over a given country could be stored onboard the orbiting vehicle for delivery by shuttle Consistent with the system shown in Figure 9 3-1, data would be transported to the proper agency authorized to disseminate the data according to international agreement It should be noted that USDI present plans call for archiving all foreign data

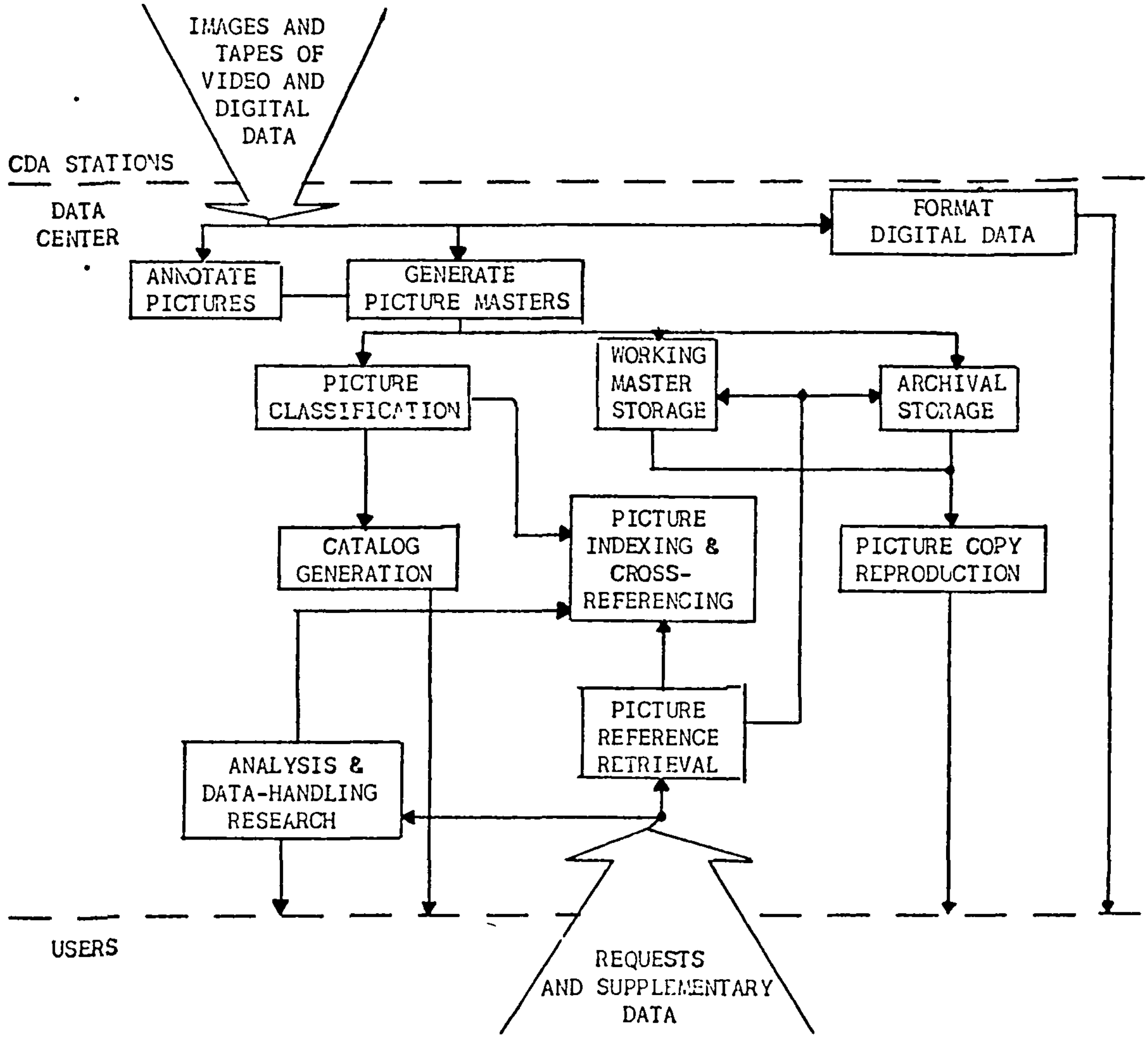


Figure 9. 3-2. Data Center

All of the above concepts are consistent with the recommendation of this study, that minimum processing be done on non-United States data and that data products be uncorrected film and tape data or RF return only

9.3.2 SYSTEM IMPLEMENTATION

Implementation of the proposed data flow system follows all of the guidelines previously laid down and assumes the availability of NASA facilities in keeping with the assignments described in Section 9 2 2 This section describes the final system and explains the final steps in its derivation Data flow throughout the system is identified in Figure 9 3 3

9.3.2.1 Data Dissemination

Dissemination studies looked at three primary functions as elements of the dissemination data flow

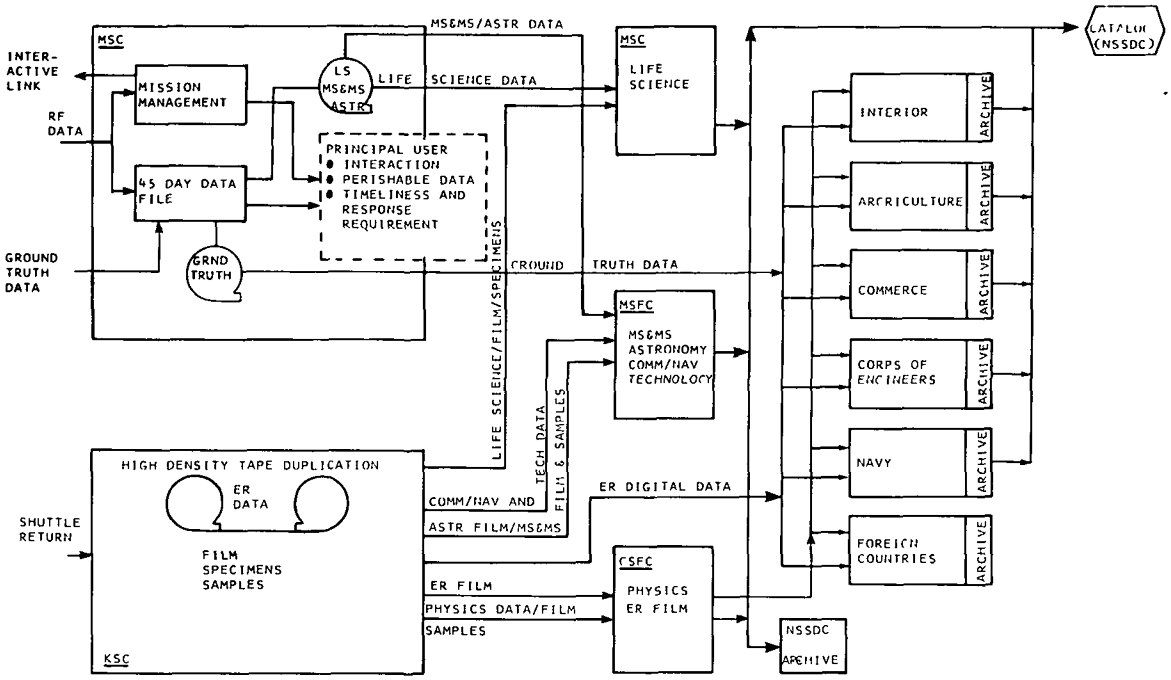


Figure 9. 3-3. Space Station Data Flow

- Data Collection – providing a means of delivering data from the orbiting spacecraft to a ground terminal for further dissemination

- Preprocessing, sorting and merging of data to present it in a form for the user Sort according to discipline or experiment, and combine with ancillary and housekeeping data

- Dissemination, transmission or transportation to a data center or user

The combination rceommended from the data dissemination task involves

- RF transmission of all electronic data

- Sort and merge on the ground involving a ground data bus and multiple mass storage devices for buffering

- Direct mail service

This combination was selected on the basis of overall cost even though initial cost was higher than another alternate

Alternative concepts were reviewed, however, on the basis of implementing a total data flow system and the combination recommended for implementation, and as shown in Figure 9 3-3 is as follows

- Shuttle return of all data except as required in real or near real time
- Sort and merge onboard the spacecraft, storing data by discipline on separate tape or film records
- Direct mail service

The recommendation is based on the following

- Lowest initial cost
- Lowest overall cost
- Potential for reduction of Shuttle return data via interaction
- Potential for nonintegrated experiment program (no Space Station)

Lowest initial cost is identified in Figure 9 3-4 where estimated costs of Concept A (Shuttle Return) and Concept B (RF Return) are compared

CONCEPT A (SHUTTLE RETURN) FUNCTION	Recurring Cost ($K/Month)	Non-Recurring Cost ($/K)	CONCEPT B (RF RETURN) FUNCTION	Recurring Cost ($K/Month)	Non-Recurring Cost ($/K)
• Shuttle Service	295		• RF Transmission	333	-----
• Sort & Merge (Onboard)	25	500	• Ground Data Bus	1	1,100
• Handling Facility	2		• Buffer Storage	25	3,000
• Direct Mail	24	1,000	• Direct Mail	24	-----
• Management	35		• Management	38	-----
TOTAL	381	1,500	TOTAL	421	4,100

Figure 9 3-4. Dissemination Concepts Cost Comparison Summary

Lowest overall cost is identified in Figure 9 3-5 where costs are projected over a ten year period. It should be noted that the operational cost of the TDRS (cost figure supplied by NASA) could be reduced if it could be demonstrated that other programs would share the TDRS service, and hence its operational cost

The potential for reduction of data load returned by Shuttle is based on the effects of interaction derived for sizing computation facilities A 4 1 reduction was identified for Earth Resources and a 3 1 for Physics Because these two disciplines provide the major proportion of the data tapes delivered via Shuttle the effects on data load reduction are dramatic A minimum of 67 tapes per month for Earth Resources, and 13 tapes per month for Physics yield a reduction of 80 tapes per Shuttle return At a cost of $440/Kg ($200/ pound) a reduction in basic operating cost of $96,000 is seen This is shown in Figure 9 3-5

The potential for nonintegrated experiment program to replace the Space Station operation appears more likely as the Space Station schedule continues to slip A multiplicity of experiments operating in differing orbits, would add severe new requirements on the TDRS beyond

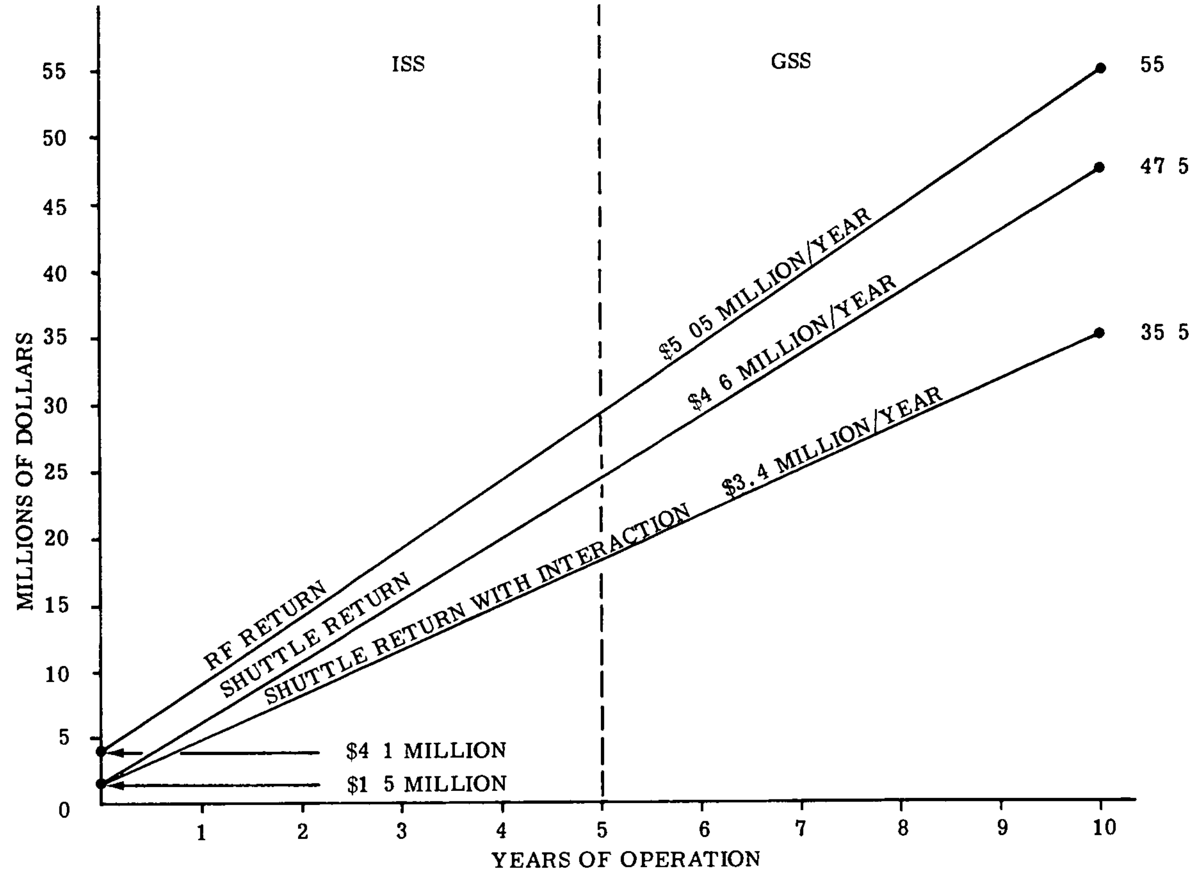


Figure 9. 3-5. Comparative Data Dissemination Costs

the capabilities specified as a guideline in this study The increased communication requirements would result in increased complexity, and in turn, increased cost

The sort and merge function has been divided into two parts Sorting is done down to the discipline level, and final sorting down to the level of individual experiments is reserved to the data center or NASA facility The same is true of merging This approach is feasible and effective because the system has been distributed on a discipline basis

9.3.2.2 Data Archiving

The archiving studies described in Section 6 identified the quantities of tape reels and film images that would accumulate in the total archive Figure 9 3-6 shows the accumulation of this data, assuming the retention requirements described earlier in Section 6 2 3 2, as a function of time

In Figure 9 3-6, record accumulation is shown without purging, and with purging based on the retention criteria At the end of 15 years, the total records are

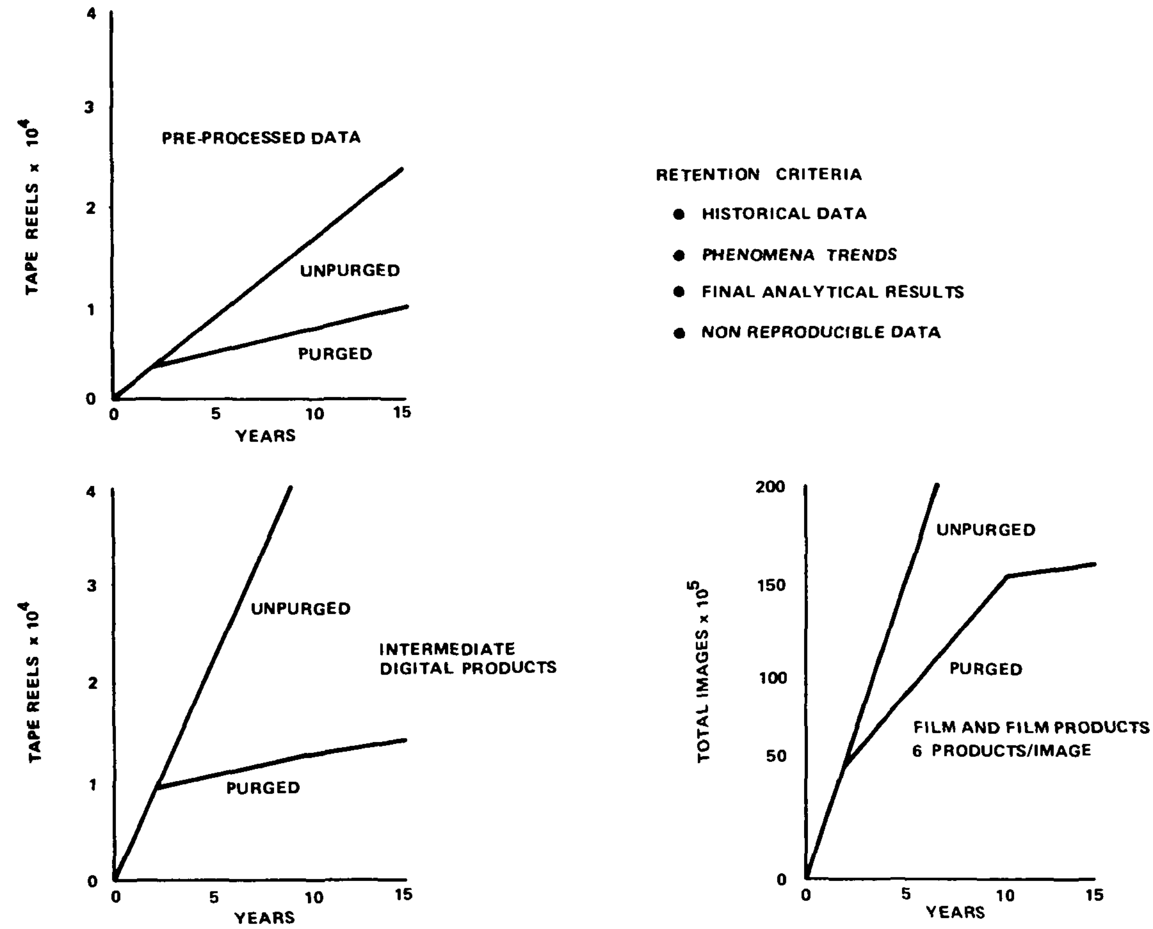


Figure 9 3-6 Data Accumulation (Purged and Unpurged) for 15 Years

Preprocessed data	10,000 Reels
Intermediate digital products	20,000 Reels
Film images	20,000 Reels

Electronic data is stored on ultra high density tape reels and film images are stored on continuous film

Storage space for these reels assuming, 3 meter (10 feet) high ceilings storage racks with 4 shelves, and 1 meter (3 feet) isles, is calculated at 252 square meters (2,800 square feet) Assuming a cost per square meter per year of $35 30 ($3 18/sq ft /yr) lease cost is approximately $8,900 per year These calculations are based on a single archive for all data stored in the system

Decentralized archives are recommended by the study, with appropriate centers maintaining records within their assigned disciplines The cost of archival space therefore becomes a factor of little importance in itself

9.3.2.3 Data Catalog

The Data Catalog represents the point of entry into the system for a user interested in search A single catalog was specified in this system because of the efficiency factor as well as likelihood of a researcher crossing disciplinary lines for correlating or corroborating data

The single catalog is recommended to be located at NSSDC for the following reasons

- Co-location of the catalog with the facilities of a Data Center permits sharing of facilities with substantial cost savings as identified in the archival study, Section 6

- Location at a NASA center enhances the ability of NASA to exercise the responsibility of Information Management This responsibility is key to the successful operation of the system since information is its total purpose

The Data Catalog is seen as an operation model of the propotype catalog currently being developed Lewis Research Center Remote terminals would be located at all Data Centers identified in Figure 9 3-2, subagencies, and appropriate user facilities, as well as all of the NASA facilities identified during this study These include the following

Manned Spacecraft Center	MSC
Marshall Space Flight Center	MSFC
Goddard Space Flight Center	GSFC
Kennedy Space Center	KSC
Lewis Research Center	LRC
Ames Research Center	ARC
Jet Propulsion Laboratories	JPL
Langley Research Center	LRC

9.3.2.4 Mission Management

Mission management changes from the traditional role of mission control to one of planning, scheduling and monitoring This comes about because of the planned autonomous operation for both the Space Shuttle and the Space Station In support of this role, which is recommended for implementation at MSC, the following facilities must be provided

- Mission Management Center

- Interaction Facility to permit users and agents to interact with experiments

- 45-Day File to store RF returned data between shuttle visits

- Dissemination Facility ofr Life Sciences, MS/MS, and Astronomy data

- Dissemination Facilities for transmitting perishable data to users

Mission management encompasses detailed planning and scheduling of experiments to pick up targets of opportunity and overcome or by-pass equipment deficienceis, as well as plan experiment programs for subsequent missions

The interaction facility permits users to operate a console that permits management of the orbiting experiment Television coverage is provided as well as voice contact with the astronauts There is provision for calling up data from the 45-day file to permit the user to compare previous data with that currently being received Presentation of data in engineering terms is provided.

Remote interaction consoles are provided in two cases In the first case, for MS/MS experiments, in many cases a control experiment is run simultaneously on the ground Since the facilities for running these experiments currently exist at MSFC, and since responsibility for this discipline is emphasized at the center, it is provided with an interaction console The communication lines to support this operation are already in existence In the second case, meteorology data is supplied via existing NOAA networks facilities, to a location designated by the Department of Commerce This is because of the perishability of the data and the need to combine this weather information gathering capability with the already operating weather systems

The 45-day file is a trillion bit storage system of the type described in Section 6 This file contains all of the data that arrives by RF over a 45-day period This permits a 15-day overlap beyond the 30 day shuttle cycle, to back up the data arriving by shuttle This file is also used to support the interaction capability

The dissemination system for Life Sciences, MS/MS, and Astronomy data is provided because this data is returned by RF only This data is reproduced from the 45-day file on UHD tape for delivery to the appropriate center as shown MS/MS and Astronomy data packages are mailed to MSFC

Dissemination facilities for transmitting perishable data to users handle not only the meteorology data previously discussed, but also such data as damage assessment, forest fire warning and similar data of an urgent nature

9.3.2.5 Data Processing

Data processing requirements were sized in Section 5 This section re-examines the previous findings in order to identify data processing recommendations in the proposed data flow system shown in Figure 9 3-2 Since the proposed system incorporates the findings of all the concept formulation tasks, reduced processing requirements result from the effects of interaction on data loads

Two disciplines are examined in detail Physics data flow was of particular interest because in the test case described in Section 9 2 2, a three-fold increase in processing capability was identified as a requirement for GSFC Earth resources data is the system driver, and consequently, the effects of interaction on this data have the greatest potential for controlling total system size

Section 4 2 3 identified a potential for reduction of physics data load by a factor of 4 1 on the basis of the operational example and discussions with users This factor has been derated to 3 1 to plan the final system size Typical factors influencing the reduction due to interaction are as follows

- Meanıngful data ın many experıments ıs only a very small portıon of total data generated by the experıment, eıther because of redundancy or because the experıment passes through the event of ınterest

- A portıon of the projected data ıs taken durıng experıment setup and stabılızatıon, and therefore, ın an ınteractıve sıtuatıon, has only real tıme utılıty

- Because of the hıghly exploratory nature of some experıments, or the dıffıculty of settıng up exact condıtıons, some experıments would be expected to be rerun several tımes before yıeldıng useful data Wıthout ınteractıon, several runs mıght be made over a perıod of months, wıth the experımenter analyzıng data ın between runs and reschedulıng and modıfyıng the experıment each tıme

The ınteractıve agent ın earth resources wıll have selectıon crıterıa avaılable to hım derıved from consıderatıons such as the followıng

- Cloud cover wıll reduce the vısıble earth surface area durıng a pass, by at least a factor of 2 1

- Sun angle wıll make data from some passes unacceptable

- Selectıon of spectral bands over certaın areas can elımınate gatherıng data ın nonproductıve bands

- Frequency of data takıng over some areas wıll cause excessıve redundancy

- Some ınstruments may be unsuıtable for certaın vıews

On the baıss of these ınfluencıng factors and deratıng the effectıveness of the operatıonal example shown ın Sectıon 4 2, a reductıon factor of 4 1 ıs used of sızıng data processıng requırements for earth resources

From the above arguments two conclusıons are reached Fırst, the processıng facılıtıes at GSFC are adqeuate for the handlıng of Physıcs data wıthout expansıon Second, the prevıously derıved fıgure (Sectıon 5 5 2 2) of 26 4 $\times$ 10^6 ınstructıons per second (2 shıft operatıon) ıs reduced by ınteractıon to 6 6 $\times$ 10^6 ınstructıons per second Thıs processıng capabılıty represents a worst case sıtuatıon and ıs requıred at those data centers whıch wıll be requıred to process all earth resources data

9.3.2 6 Data Centers

An essentıal part of the baselıne concept ıs the Data Center, whıch combınes the responsıbılıty of preprocessıng, archıvıng, and user servıces, Fıgure 9 3-2 ıdentıfıes the assıgnments of responsıbılıtıes as presently recommended

The NASA centers are natural selectıons because the followıng resources wıll already be avaılable

Processıng Facılıtıes

Archıvıng Facılıtıes

Software

Procedures

Consequently, only selected elements need be added, to adapt the existing capabilities to the data flow system

In the case of earth resources, assignments were made to the various agencies and foreign countries that require earth resources data There is a lot of duplication in the earth resources area since the same raw data contains much information and each of the agencies will extract different types of information from the same raw data The Department of Commerce, and Department of Interior would utilize all of the earth resources data generated and the Department of Agriculture, Corps of Engineers, and Navy would utilize subsets in accordance with their needs

9.3.2.7 Tape Duplication at KSC

On the shuttle return, there is a requirement for the earth resources data to be duplicated for shipment to other government agencies Since the study assumes shuttle return to KSC, this duplication facility should be implemented at KSC From the earth resources investigation, a combination of the Department of Interior and the Department of Commerce will get all Oceanography and United States earth resources data The other agencies recommended for data centers will use subsets of this data, and therefore these subsets must be duplicated In addition, there will be some overlap especially in the coastal areas, between the Department of Interior and the Department of Commerce which justifies the need for further earth resources data duplication. Since KSC is responsible for the dissemination of data in all other disciplines, it would be less expensive to duplicate the data as the tapes arrive from the shuttle and ship all data directly to the data centers by mail

9.3.2.8 Image Processing at GSFC

An image processing capability implemented at GSFC for the ERTS program is reflected in Section 9 2 2 2 as excess processing capability The capability includes a wet processing line for photographic development and a processing facility capable of making radiometric and geometric correction Measured against the requirement in the data flow study to process 36,000 frames per month, the 40,000 frame capability at GSFC is completely adequate End products from this facility in the form of ten copies each of the 36,000 inputs per month as planned to be mailed to the appropriate centers as shown in Figure 9 3-2

9.4 POST ISS EVOLUTION

Study of Case 534G shows that during the transition from ISS to GSS, data rates will increase by an order of magnitude Most of this growth is due to the introduction of extensive astronomy experiments plus a 25 percent increase in Earth Reosources data In Earth Resources, two significant trends will predominate.

1 Requirements for coverage will increase in all aspects spectral, spatial, and temporal

2 A data base will have been established during ISS, and maintenance and modification of the data base will replace the task of building it

Increased coverage, spatially will be in terms of providing remote sensing over foreign territory This will have a minimal effect on the proposed data handling system since data is proposed to be delivered expeditiously with minimum handling in the United States

Increased coverage, spectrally will come in the form of finer resolution as new instrumentation is introduced into the remote sensing facility, and new applications are developed which can capitalize on the finer resolution data

Increased coverage, temporally should come in the form of localized investigations since profiles of seasonal variations should have been developed by that time as well as means of updating and maintaining the profiles

The ERTS and EREP programs will have provided the means to develop the structure of an Earth Resources data base Building on this structure in the ISS time period should provide a comprehensive data base, describing the continential United States and permitting users to meet their application requirements In the transition to GSS, the full effect of interaction should be felt as the agency responsible for building the data base upgrades the data base, concentrating on expanding coverage, filling gaps, improving resolution and meeting special requests for coverage

The conclusion to be drawn from these considerations is that the data handling system should not be impacted by massive increases in Earth Reosurces data as the system grows beyond ISS

Most of the data rate growth, however, from ISS to GSS is in the Astronomy discipline It should be noted that this is a characteristic of the particular, hypotethical, experiment program, 534G, that was selected to guide this study Furthermore, only two astronomy experiments generate almost all of the data responsible for the data rate growth

Even though the data rates are increased by an order of magnitude from ISS to GSS, there are a number of reasons for concluding that the presently existing and planned facilities for ISS will be able to handle the data flow problem as it emerges in the latter period

- Data compression techniques were determined to be particularly beneficial in the Phase B study program By the time period in question, any of several promising techniques will be available, including optical processing

- Interaction with the option of lower resolution sampling and transition to higher resolution sampling on demand offers a distinct opportunity to reduce data flow substantially

- Evolutionary improvements in data handling facilities, simply by replacement with next generation processing equipment, offers the ability to cope with the increased data load Here it should be noted that in the Case 534G, no Physics experiments are programmed during the GSS period Combining the GSFC facilities then, with the MSFC/Slidell facilities makes available about one-fourth the data processing capability projected for handling the raw Astronomy data projected for the GSS period

DATA FLOW PLAN (IMPLEMENTATION) 10

10.1 INTRODUCTION

This section of the Space Station Data Flow Study Report is a plan for implementation of the system as described in the previous sections Because the system represents largely a growth of already existing systems this plan is essentially a change pattern In turn, the elements of the plan are presented on the basis of deltas, or changes to the existing systems The elements of the plan include descriptions of hardware items, facilities, and personnel, and schedule milestones and estimated costs

10.2 DATA FLOW

Data flow throughout the system is identified in Figure 10 2-1 The essential elements of this system are described in this section

10.2.1 DATA SOURCES

The primary source of data is the Space Station complex which provides, through the TDRS and by Shuttle delivery data from experiments in free flying modules and orbiting shuttles as well as the experiments in the Modular Space Station itself Current NASA planning calls for all of these sources to communicate via the Space Station as shown in Figure 10 2-1

All experiment data is made available for transmission to the ground via the on-board Information Management System Two special capabilities have been recommended for inclusion in the Information Management System

On-board buffering is required, to obviate a ten minute communication gap in the TDRS and to hold data planned for transmission on the next orbit or later This is required for both analog and digital data

Recording of data on a single tape per discipline and on a single tape per Earth Resources run, requires additional tape drives, but reduces ground data processing Recording of housekeeping data on these same tapes reduces ground data processing further

Aircraft underflight data, in support of the Earth Resources experiments is expected to be supplied to the Department of Interior where it will be archived to support the analysis of data by users in this field Data sources for this purpose include the MSC Resources Aircraft program described in Section 8 3 3 and the United States Geological Survey (USGS) which continuously photomaps the continental U S completing the cycle every seven years

Ground truth data flow is shown in Figure 10 2-1 from one of a large number of expected sites that would be required in the era of the Space Station Data flow is primarily to the Data Centers identified in Section 9 3 for handling Earth Resources data Data from these sources would be expected to be stored and cataloged in a manner similar to that for remote sensed data from the Space Station or the Aircraft Underflight program

Current ground truth data must also be available to the interactor who is involved in the real time interactive operations at the Mission Management Center Timely data on local conditions will assist him in making decisions on data gathering in terms of scheduling and programming instruments

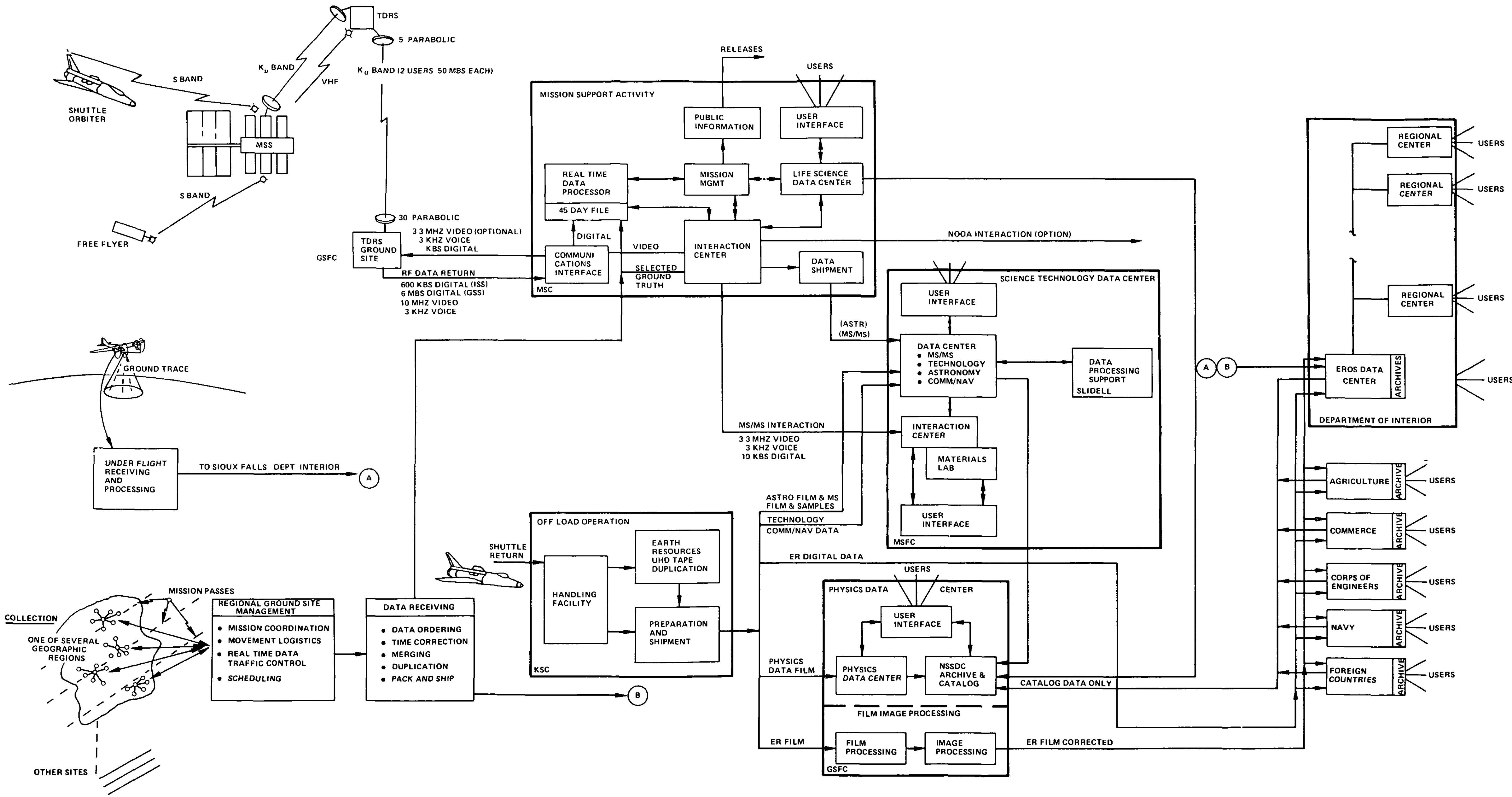


Figure 10 2-1 Space Station Data Flow

10.2.2 DATA CENTER FUNCTIONS

The primary role of the Data Center is to serve users This is done by collecting and maintaining (archiving) data, calibrating and correcting data, assisting in data searches, and on request, processing data for users The Centers also enter data processed by users into the system, along with catalog and abstract data required to be generated by the user In addition, the centers must provide feedback in the system, by way of processing requests for data, back through the system to the Mission Support Activity

10.2.2.1 Earth Resources Data Centers

Earth Resources Data Centers are exemplified by the EROS Data Center operated at Sioux Falls, South Dakota by the Department of Interior Users are served directly by visit or may be served by mail request by telephone, or through one of the regional centers distributed around the country A network of perennial users would be expected to evolve, taking advantage of their own catalog terminals, and establishing standing requests for periodic data

These centers are all seen operated by agencies other than NASA, but, under interagency agreement, they are operated through a common catalog located at NSSDC Truth site data and underflight data are envisioned entering the system primarily through the center shown for Department of Interior

10.2.2.2 Science/Technology, Life Science, Physics Data Centers

Science/Technology Data Centers are indicated within NASA facilities They include the Physics Data Center at GSFC serving that portion of the scientific community It should not be assumed that this is the only portion of the community that would be served, however, since each of the Data Centers would have access to the Data Catalog and be able to assist in conducting a data search in any discipline

The Data Center at MSFC is assisted in its data processing by the Slidell Data Processing Center

The Life Science Data Center at MSC is in a position to support Mission Management in its crew safety role

It is especially true of these Data Centers that they would create a reverse flow of processed data, into the system, from experimenters along with supporting indexes and abstracts for the catalog

10.2.3 COMMUNICATIONS

The principal communication links required for operation of the Data Flow system consist of the following

10.2.3.1 Space Station External Communications

Space Station to Mission Support Activity is provided through the Tracking and Data Relay Satellite (TDRS) The RF requirements identified in Section 2 4 4 1 for data return, and in Section 4 3 2 for user interaction are satisfied Since the ground station for TDRS is located

at GSFC, the present 50 KBS line from GSFC to MSC would be required to be expanded to 600 KBS to satisfy the Mission Management function at the latter location. No intermediate switching site is shown in Figure 10 2-1 since one has not yet been identified

10.2.3.2 Remote Interaction Support Communications

Remote interaction support communications from Mission Support Activity to the Materials Laboratory facilities at MSFC consist of a video transmission line and telephone circuits Interaction requirements exist for a maximum of 63 hours per month, averaging about two hours per day that the facilities must be available

10.2.3.3 Real Time Transmission to NOAA

Optional real-time communications from Mission Support Activity to NOAA depend upon two factors

- A choice by NOAA to operate remotely, rather than provide an operator at MSC in the Interaction Center
- Identification of a site where data would be received

It is assumed that the cost of facilities to transmit to a remote site would be borne by NOAA

10. 2.3.4 Catalog Terminal Communications

Telephone line networks operating on a dial-up basis would support a number of catalog terminals located at the facilities serving users, to permit their access to the centralized catalog

10.2.4 OFF-LOAD OPERATIONS AND DATA SHIPMENT

Shipment of Shuttle returned data is initially from the off-loading facilities indicated at KSC Digital data tapes containing Earth Resources data are duplicate, to permit distribution to more than one location Each of the locations is a Data Center operated by a government agency other than NASA Shipment from KSC is by U S Mail Subsequent shipment of data is also by mail, including

- Processed data from NASA Data Centers to archives at NSSDC
- Undeveloped Earth Resources film from KSC to GSFC
- Processed film from GSFC to Earth Resources Data Centers
- Aircraft underflight data to Earth Resources Data Centers
- Truth data to ER Data Centers

10.2.5 MISSION SUPPORT ACTIVITY

The Mission Support Activity shown at MSC in Figure 10 2-1 includes the Mission Management functions of planning, scheduling, coordinating, and monitoring Management of the

Interaction Center is a prime responsibility This operation center permits several experimenters to interact with experiments ongoing in the Space Station

The Life-Sciences Data Center co-located at MSC is able to support Mission Management in the area of crew safety

The real time data processor consisting basically of the present Real Time Computer Complex (RTCC) supports the management functions and the real time interactions functions The 45 day storage retains real-time data, making it available to the interacting experimenter, and providing temporary storage until duplicate data is returned via Shuttle

Release of information, including real time television coverage is anticipated, to maintain an awareness of the program on the part of the public

10.3 SYSTEM IMPLEMENTATION

Figure 10 3-1 summarizes the features of the hypothesized implementation of a Space Station Data Flow System This section describes these features

10.3.1 MODULAR SPACE STATION INFORMATION MANAGEMENT SYSTEM

Digital and video buffers onboard the Space Station hold data during the TDRS communication gap, and between orbits Five additional tape recorders onboard, permit recording without mixing disciplines on any single tape

10.3.1.1 Equipment

Ultra High Density Tape Transports - 5 Each

Bits per reel	2 65 x 10^{10}
Channels	48
Bits per channel cm	3945
Tape speed	50 8 cm/second
Tape width	2 54 cm
Tape length	1402 meters

10.3.1.2 Software

No additional software cost

10.3.1.3 Operations

Minimal additional procedural requirements for tape handling No special training or additional personnel

10.3.1.4 Cost Estimate

Estimated non-recurring cost for implementing 5 tape recorders - $500,000

FUNCTION	IMPLEMENTATION	LOCATION	AVAILABILITY	SOFTWARE	FACILITY SPACE	PERSONNEL	TRAINING	PROCEDURES
Onboard Buffer	Digital Data Buffer Video Data Buffer	Space Station	Available	---	---	---	---	---
Onboard Record By Discipline	5 UHD Tape Recorders	Space Station	Procure	---	---	---	---	Minimal
Uplink Video	Transmitter	GSFC	Procure	---	---	---	---	---
Mission Management	• Communication Equip. • Interaction Consoles • Catalog Terminal • Data Processor	MSC	• Procure • Procure • Procure • Available	Required	Revamp	Available	Required	Required
Shuttle Off-Load	• UHD Tape Duplicator • Handling Facilities • Shipping Facilities	KSC	• Procure • Available • Available	---	Revamp	---	Handling Training	Required
Digital Data Processing	Existing Facilities	MSC, GSFC MSFC/Slidell	Available Expand	Available	---	---	Minimal	Minimal
Archiving	Existing Facilities	GSFC	Available	---	Minimal	--- Available	Minimal	Expand/ Develop
	Catalog Terminal	GSFC	Procure					
Catalog	Trillion Bit Store	GSFC	Procure	Expand	Required	Operational Maintenance	Required	Expand
Remote Interaction	Interaction Console	MSFC, NOAA	Procure	---	Required	Experimeter &Maintenance	Required	Minimal
Film Development	Wet Process Line	GSFC	Available	---	Available	Available	---	---
Image Processing	RAD/Geom Correct Facility	GSFC	Available	---	Available	Available	---	Available
	Scan Straightener	NOAA - USDI	Development		Available	---	---	None

Figure 10 3-1 Data Flow Implementation Elements

10.3.2 R. F. DATA RETURN

The Tracking and Data Relay Satellite (TDRS) System satisfies all of the RF return requirements for ISS and GSS periods.

Uplink video is considered as an option whose value must yet be measured In the interactive mode it would strengthen spacecraft to ground communications by permitting astronauts to view the interactor or a ground-based control experiment. Communication would be through TDRS.

10.3.2.1 Equipment (for Uplink Video option only)

Video Camera	- at interaction site
Ku Band Transmitter	- at GSFC
Modulator	- at GSFC
Video Link	- interaction site to GSFC

10.3.2.2 Software

None

10.3.2.3 Operations

No special procedures or training, or additional personnel.

10.3.2.4 Cost Estimate (optional)

Non recurring (video link)	- $50,000
Recurring (video link)	- $80,000/month

10.3.3 MISSION SUPPORT ACTIVITY

Mission Support Activity implementation at MSC involves significant changes in facilities and operations Facility modifications include the refurbishment to change from the present Mission Control Function to that of Mission Management The addition of a catalog terminal provides user access to a data catalog, proposed for central location at NSSDC

Modifications to communication facilities consist of upgrading of leased lines for communications between MSC and GSFC where TDRS ground facilities are planned, and the installation of terminal equipment at MSC Definition of an initial incremental change is expected to be derived in the study of a specific shuttle mission (contract mod)

Data Processing facilities in the Real Time Control Computer Complex (RTCC) would be rededicated to the Mission Management task Basic equipment in this complex consists of

- 4 IBM 360/75 computers with J Memory
- 4 Megabyte LCS (storage)

A replacement of these computers within the late 1970's with next generation hardware, should provide an improved throughput to cost ratio

A 45 Day Data File and three interactive operator consoles are included in the system This trillion bit memory is being integrated into the RTCC at the present time Local interactive operator consoles incorporate two way voice communication, data bank call-up and display of imagery and engineering data Similar consoles located remotely require integration into the system as shown

10.3.3.1 Equipment

Communication Facilities

3 230 Kbs lines - lease
3 Modems - lease

Interface Control Unit (controls data flow from 230 Kbs lines to Computer complex)

Catalog Terminal

Small graphics terminal with processing capability and display capable of interfacing with telephone line up to 1200 baud

Special DP Facilities

UHD Tape Recorder with Computer Interface

Data Rate - 9 6 megabits/second
Channels - 48
Bits per reel -2 65 x 10^{10}
Bits per channel cm - 3945
Tape Speed - 50 8 cm/sec
Tape Width - 2 54 cm
Tape Length - 1402 m

Interactive Operator Console (3 each)

Voice Communication - 2 way
Engineering Data Display - CRT
Image Display (2 each) 1000 lines (Multispectral scanner option - conical scan)
Call-up Capability - capability to call up displays from computer or 45 day data file
Video Display (TV) 2 channels

10.3.3.2 Software

Software to support the Mission Management functions of experiment scheduling, quality control, real-time distribution and interaction would be integrated into the system as hardware elements are added. Completion of initial hardware and software integration is in time for ISS in 1980 Periodically, new software elements would be developed and integrated as new experiments and modules are added to the Space Station Complex over the 10 year ISS/GSS period

Software to support the Life Sciences Data Center at this location would be developed and modified on the same schedule as for Mission Management software

10.3.3.3 Operations

Procedures and training courses would be developed and personnel trained in the Mission Management functions

Training classes would continue beyond the schedule shown in order to train user personnel and experimenters

At the present time, the Flight Controller Team at MSC is estimated at 194 personnel including ground station, computer operations and other support personnel, during peak periods In off-peak periods personnel return to management, planning and evaluation roles This number of personnel operating at a steady rate without peaks in the Space Station era represents an adequate operating force, with the possibility for reduction in number in the ISS period

10.3.3.4 Cost Estimate

Non-Recurring Costs

Facility Modifications	$ 100,000
Installation 690 KBS Link	1,000
Interface Control Unit	50,000
Catalog Terminal	10,000
UHD Tape Recorder (10)	1,500,000
Interactive User Consoles (3)	1,500,000
Mission Support Software	60,000,000
Documentation	10,000,000
Procedures	10,000,000
Training	1,000,000

Recurring Costs

See Table 10.5-2

10.3.4 SHUTTLE OFF-LOAD

KSC has been recently designated as launch site for the Space Shuttle In keeping with this decision the logistics facilities will be available prior to Shuttle operational flights These facilities will be fully capable of handling the companion functions on Shuttle return from operational missions including shipping as required for dissemination of returned data

A UHD tape duplication facility would be required, to prepare tape copies for distribution of Earth Resources data

10.3.4.1 Equipment

UHD Tape Duplicator - 2 each

Input	UHD Tape
Output	Multiple Tapes
Throughput	9 6 megabits/second

10.3.4.2 Software

None required if tape duplicator system is operated off line

10.3.4.3 Operations

Procedures are required but are minimal Operator must be provided on a part time basis Recycling of tapes is anticipated in order to maintain low cost

10.3.4.4 Cost Estimate

Non-Recurring Cost

UHD Tape Duplicators (2)	$500,000

Recurring Cost

See Table 10.5-2.

10.3.5 SCIENCE TECHNOLOGY DATA CENTER

Digital Data Processing facilities at MSFC have been judged adequate to handle the Science and Technology data load The same opportunity to upgrade the processing facilities in the RTCC with a new generation of hardware, is seen for this center A similar improvement in throughput to cost ratio is seen UHD Tape Recorder adaptation would be required, at both MSFC and Slidell

The remote interaction console would communicate with the interaction center at MSC through leased lines See Section 10 3 6

10.3.5.1 Equipment

UHD Tape Recorder with Computer Interface (2)

Data Rate	9 6 megabits/sec
Channels	48
Bits/Reel	2 65 x 10^{10}
Bits/Channel cm	3945
Tape Speed	50 8 cm/sec
Tape Width	2 54 cm
Tape Length	1402 meters

Catalog Terminal See Section 10 3 3 1.

10.3.5.2 Software

Minimal software required to handle UHD Tape Interface, Scientific data processing software at the NASA centers is expected to be available, but must be expanded

10.3.5.3 Operations

Operations, in general, are anticipated on a two shift basis and require no additional personnel Minimal procedure development and training are anticipated

10.3 5.4 Cost Estimate

Non-Recurring Costs

UHD Tape Recorders (4)	$ 600,000
Software	10,000,000
Catalog Terminal	10,000

Recurring Costs

See Table 10 5-2.

10.3.6 REMOTE INTERACTION

Remote console at MSFC would operate through leased lines from MSC to MSFC

10.3.6.1 Equipment

Interactive Operator Console

Same as in Section 10 3 3 1 but with communication line interface Space provided by user

10.3.6.2 Software

None

10.3.6.3 Operations

Minimal modification of procedures required in Section 10 2 4 3 for local MSC use. No increase in personnel since consoles would be manned by experimenters

10.3.6.4 Cost Estimate

Non-Recurring Cost

Interactive Operator Console	$ 500,000

Recurring Cost

See Table 10.5-2

10.3.7 PHYSICS DATA CENTER

Digital Data Processing facilities at MSC and GSFC have been judged adequate to handle the Physics data load The same opportunity to upgrade the processing facilities in the RTCC with a new generation of hardware, is seen for this center A similar improvement in throughput to cost ratio is seen UHD Tape Recorder adaptation would be required

Archiving, Catalog and Film Image Processing Facilities are also located at GSFC See Sections 10 3 8, 10 3 9 and 10 3 10

10.3.7.1 Equipment (at each location)

UHD Tape Recorder with Computer Interface

Data Rate	9 6 megabits/sec
Channels	48
Bits/Reel	2 65 x 10^{10}
Bits/Channel cm	3945
Tape Speed	50 8 cm/sec
Tape Width	2 54 cm
Tape Length	*1402 meters*

Catalog Terminal See Section 10 3 3 1.

10.3.7.2 Software

Minimal software required to handle UHD Tape Interface, Scientific data processing software at the NASA centers is expected to be available, but must be expanded

10.3.7.3 Operations

Operations, in general, are anticipated on a two shift basis and require no additional personnel Minimal procedure development and training are anticipated

10.3.7.4 Cost Estimate

Non-Recurring Costs

UHD Tape Recorder (2)	$ 300,000
Software	5 ,000,000
Catalog Terminal	10,000

Recurring Costs

See Table 10.5-2

10 3.8 ARCHIVING

Archival of Science and Technology data at the NSSDC at GSFC using, primarily, UHD tape requires minimal space and little personnel training Procedures for conduct of search would have to be adapted, based on the catalog system developed by Lewis Research Center A Catalog Terminal similar to that described in Section 10 3 3 1 would be required.

10.3.8.1 Equipment

Catalog Terminal

Small graphics terminal with processing capability and display capable of interfacing with telephone line up to 1200 baud

10.3.8.2 Software

None

10.3.8.3 Operations

No personnel increases would be required However, procedures would have to be developed, including interagency agreements on archiving, purging, etc

10.3.8.4 Cost Estimate

Non-Recurring Costs

Catalog Terminal	$ 10,000
Archiving Procedures	10,000,000

10.3.9 CATALOG

Implementation of the catalog developed by Lewis Research Center would require expansion to serve the seven disciplines rather than only Earth Resources as at present The catalog is designed to operate in any large IBM 360 computer installation Addition of large storage capacity would be required At each of the entry contributing centers an abstracting capability must be implemented GSFC is designated as the catalog location

10.3.9.1 Equipment

Trillion Bit Store

Storage Capacity	1 x 10^{12} bits
Throughput	4 x 10^{6} bits/sec
System Access (off-line)	9 seconds
System Access (on-line)	0 2 seconds

10.3 9.2 Software

Application software must be developed, based on the Lewis Research Center prototype system, but expanded to include all seven disciplines

10.3.9.3 Operations

Operation of the catalog locally is expected to require no additional personnel or space except as required by the addition of the Trillion Bit Store

Procedures must be developed concurrent with the software to control access Methods for abstracting and controlling entry of abstracts must be developed Abstracts of raw data would be done by the appropriate centers, NASA, or other government agencies. Abstracts of processed data would be required to be submitted by the user when he submitted the processed data to the archives Purging procedures must be developed

10.3.9.4 Cost Estimate

Non-Recurring Costs

Trillion bit store	$ 1,600,000
Application Software	10,000,000
Procedures	5,000,000

Recurring Costs

See Table 10.5-2.

10.3.10 FILM IMAGE PROCESSING

Wet process facilities are anticipated to be available from the ERTS program and adequate in capacity

Radiometric and Geometric correction facilities at GSFC used in conjunction with the wet process line for ERTS are anticipated to be adequate to handle the film Earth Resources data load from the Space Station assuming like handling (corrections).

10.3.10.1 Equipment

None additional

10.3.10.2 Software

None

10.3.10.3 Operations

No additional procedures or personnel

10.3.10.4 Cost Estimate

None

10.3.11 EROS DATA CENTER

This non-NASA Data Center would operate in conjunction with regional centers to service users. UHD Tape Recorder with computer I/O would provide interface

10.3.11.1 Equipment

Scan Straightener

Input	UHD tape (digital)
Output	UHD tape (digital)
Input Format	Conical
Samples per scan (in)	4800
Bits per sample (in)	9
Output Format	Rectilinear
Samples per scan (out)	1150
Bits per sample (out)	9
Throughput	9 6 megabits/sec

UHD Tape Recorder with Computer Interface

Data Rate	9 6 megabits/sec
Channels	48
Bits/Reel	$2\ 65 \times 10^{10}$
Bits/Channel cm	3945
Tape Speed	50 8 cm/sec
Tape Width	2 54 cm
Tape Length	1402 meters

10 3.11.2 Software

To be developed by Department of Interior, including special analysis software for user service Cost not chargeable to NASA Data Flow System

10.3.11.3 Operations

Responsibility of Department of Interior

10.3.11.4 Cost Estimate

Non-Recurring Costs

Scan Straightener (optional)	\$3,250,000
UHD Tape Recorder	150,000

10.3.12 OTHER DATA CENTERS

Other Data Centers operated by departments of Agriculture, Commerce, Army, Navy and a possible Data Center to service foreign users would have similar implementation requirements

10.3.12.1 Equipment

UHD Tape Recorder
Scan Straightener (optional)
Interactive Operator Console (NOAA)

10.3.12.2 Software

Requirements similar to Section 10 3 11 2 for each agency

10.3.12.3 Operations

Requirements similar to Section 10 3 11 3 for each agency

10.3.12.4 Cost Estimate

Non-Recurring Costs (each center)

UHD Tape Recorder	$ 150,000
Scan Straightener (assume for Commerce only)	3,250,000
Interactive Operator Console (assume Commerce only)	500,000

10.4 MILESTONE SCHEDULES

Basic milestone schedules are shown in Figure 10 4-1 For purposes of determining start date of modifications, it is assumed that a program including Skylab A, U S /Soviet joint space ventures and a possible Skylab B will be completed by year end 1976 This determines a start date. End date is constrained by the 1980 ISS time assumed throughout the study and an additional postulation of operational Sorties flights, with real-time communications in 1979 TDRS is considered available in 1979

10.5 PROGRAM COSTS

Program Costs are summarized as follows All costs are engineering estimates, and do not commit IBM to this scope, in part or in total

10.5.1 NON-RECURRING COSTS ($ THOUSAND)

Table 10 5-1 Non-Recurring Costs Estimate

Quantity	Item	Reference Section	Cost Estimate
5	Procure Onboard Recorders (max)	10 3 1 4	500
	Facility Modifications	10 3 3 4	100
3	230 Kbs lines with Modem	10 3 3 4	1
1	Interface Control Unit	10 3 3 4	50
1	Catalog Terminal	10 3 3 4	10
10	UHD Tape Recorder w Computer I/O	10 3 3 4	1,500
3	Interactive Operator Console	10 3 3 4	1,500
	Develop Mission Management Software	10 3 3 4	60,000
	Documentation	10 3 3 4	10,000
	Procedure Development	10 3 3 4	10,000
	Training	10 3 3 4	1,000

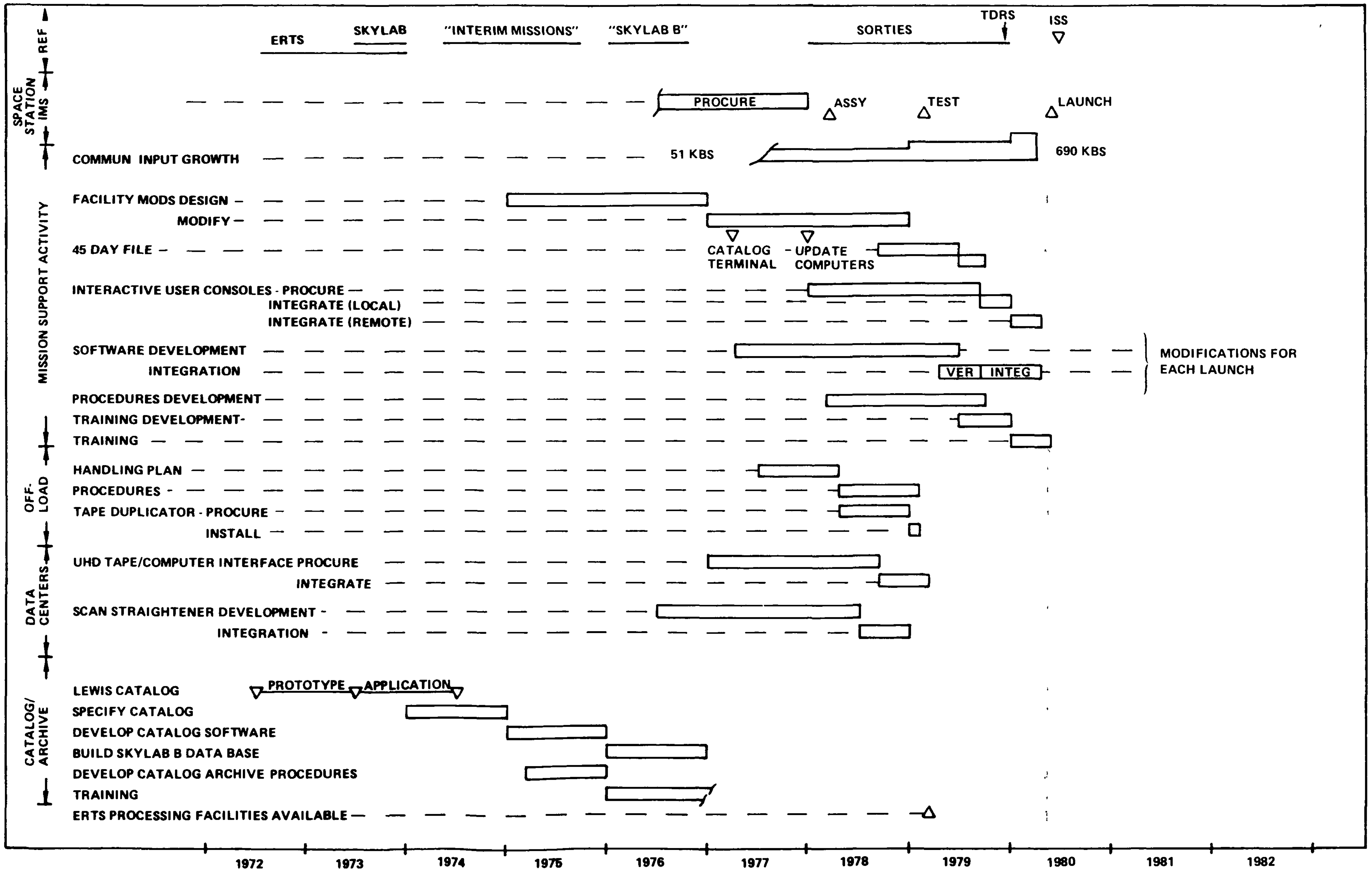


Figure 10 4-1 Data Flow Implementation Schedule

Table 10 5-1. Non-Recurring Costs Estimate (cont)

Quantity	Item	Reference Section	Cost Estimate
2	UHD Tape Duplicators	10 3 4 4	500
4	UHD Tape Recorder w Computer I/O	10 3 5 4	600
	Develop Software MSFC Data Center	10 3 5 4	10,000
1	Catalog Terminal	10 3 5 4	10
1	Remote Interaction Console	10 3 6 4	500
2	UHD Tape Recorder w Computer I/O	10 3 7 4	300
	Develop Software GSFC Data Center	10 3 7 4	5,000
1	Catalog Terminal	10 3 7 4	10
1	Catalog Terminal	10 3 8 4	10
	Develop Archiving Procedures	10 3 8 4	10,000
1	Trillion Bit Store	10 3 9 4	1,600
	Develop Application Software	10 3 9 4	10,000
	Develop Procedures	10 3 9 4	5,000
1	Scan Straightener	10 3 11 4	3,250
1	UHD Tape Recorder	10 3 11 4	150
5	UHD Tape Recorder	10 3 12 4	750
1	Scan Straightener	10 3 12 4	3,250
1	Remote Interaction Console	10 3 12 4	500

10.5.2 RECURRING COSTS ($ THOUSANDS/MONTH)

Table 10 5-2 Recurring Costs Estimate

Quantity	Item	Reference Section	Cost Estimate
3	Leased Lines - 230 Kbs GSFC/MSC	10 3 4 4	78
	Shuttle Service	10 3 5 4	295
	Direct Mail	10 2 4	24
	Tape Duplication	10 3 5 4	25
	Software Maintenance	10 3 4 4	16
	Documentation Maintenance	10 3 6 4	16
1	Leased Line MSFC/MSC (Video, Voice, 2400 bps)	10 3 9	40
	Management	10 3 8 4	28
	Total		421